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A Study and Economic Appraisal of the Effect of Nitrogen Fertilization and Selected Varieties on the Production and Processing of Sugar Beets

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Received for publication February 24, 1958.

Introduction

During recent years, the problem of declining net extraction in the beet sugar industry has focused attention on factors which influence the type and amount of nonsugars entering the process (15, 16, 9).[2] Increased availability and use of commercial fertilizers are known to be one of these factors (11, 13, 17). In addition, new varieties have been introduced periodically with little or no thought given to their possible effect on the process.

Since the upward trend in the use of nitrogen fertilizers continues and the possibility now exists for developing new varieties with reduced amounts of certain nonsugars, there is need for experimental data concerning the influence of nitrogen fertilization and varieties on the production and processing of beet sugar. Moreover, since production and processing of sugar beets are commercial ventures, the above mentioned problems should also be evaluated on a monetary profit and loss basis. With these problems in mind the experiment reported herein was designed to study the effect of three levels of nitrogen fertility and seven sugar beet varieties on production and extraction of sugar. A concerted effort was made throughout to obtain data which would permit realistic dollar values to be assigned for an economic appraisal of the results obtained.

Materials and Methods

The field selected for the test was a sandy loam soil located in the Nyssa, Oregon district and had a cropping history of beets, grain, and corn with no nitrogen fertilizer applied to the corn crop. During the previous season the corn showed extreme nitrogen deficiency symptoms indicating a low level of nitrogen fertility.

The experimental design was a randomized split plot with eight replications. Seven varieties were planted as the main plots, 18 rows wide and 40 feet long. Each main plot was divided into

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[2] Numbers in parentheses refer to literature cited.

three six-row subplots for the three separate levels of nitrogen fertility. Each replication was separated by a three foot alleyway.

The plots were planted on April 7, 1955, using 22-inch row spacing. The varieties included in the test were:

1. SLC 824 (US 35/2)—An open pollinated, high sugar, curly-top resistant variety.
2. C-51-1—A new potential commercial variety derived from rigid selection for high sugar and low sodium content within an open pollinated variety.
3. A2-90H0 (CT9)—The male sterile equivalent of a curly-top resistant inbred line which is relatively low in sucrose content.
4. US 22/3—A standard open pollinated tonnage variety with excellent curly-top resistance but low sucrose content.
5. US22S—Currently used commercial variety resulting from a blend of SLC 824 and N47.
6. F54-2H—A monogerm hybrid.
7. 4323SB—A "hybrid" between A2-90H0 and SLC 824 produced by blending the seed of the parental lines prior to planting the commercial seed field.

During spring seedbed preparation of the fall plowed land, 126 units of P_2O_5 and 65 units of nitrogen in the form of granular fertilizers were disced into the soil. This was done to provide an adequate level of P_2O_5 for the season and sufficient nitrogen to support early growth on all plots.

Additional applications of nitrogen were applied in the form of anhydrous ammonia by side dressing in alternate furrows midway between the rows and at a depth of six inches. A metering pump was used to regulate the amount of fertilizer applied. On June 9, 75 pounds of nitrogen per acre were applied to the medium and high fertility plots thus raising the level on these plots to 140 units per acre. Again on July 5, in two separate applications of 70 lbs. each, 140 lbs. of nitrogen per acre were applied to the high nitrogen plots. Thus, the three rates of nitrogen fertilization were established at 65, 140, and 280 pounds per acre.

Locally accepted practices of cultivation and irrigation were followed. The alternate rows in which the fertilizer was injected were used for irrigation until the last two irrigations when the water was changed to the alternate set of rows.

Petiole samples were taken just prior to harvest according to the method outlined by Ulrich (18). Each sample consisted

of 30 to 40 petioles taken at random from the two center rows of each subplot.

The plots were harvested on October 13. To reduce possible border effects, 18 inches of row were discarded from each end of all plots and only the two center rows of each subplot were harvested for yield measurements and to supply roots for processing. Two ten-beet samples were taken from each subplot to determine sucrose content at harvest. An additional 150 pounds of beets from each subplot were placed in cold storage for the processing studies conducted at Central Laboratory, Twin Falls, Idaho.

Beets from each subplot were removed from storage for processing at such a time as to provide an equal storage period for each variety-nitrogen level condition. Thus storage time did not become a variable.

Upon removal from storage the beets were washed and sliced into cossettes which were thoroughly mixed. Samples of the cossettes were analyzed for sugar, sodium, and potassium (8). Samples were also furnished to International Minerals and Chemical Corporation, Research Laboratory, Woodland, California, for glutamic acid assays by the microbiological method (10). Juice prepared from the cossettes was analyzed for apparent purity (12), total nitrogen including that in the form of nitrate (1), phosphate (7), total ash (2), invert sugar (3), and raffinose (4). The amino nitrogen compounds were estimated by boiling 10 ml. of the juice with three pellets of pure sodium hydroxide almost to dryness, determining the nitrogen content of the residue (1), and multiplying this result by a factor of 7.5.

The cossettes were processed in a continuous, countercurrent flow, pilot diffuser under the following conditions:

Temperatures: First 15% of cossette travel—82° C.
Remainder of cossette travel—70° C.
Retention time: 36 minutes
Pulp, % Sugar: 0.18
Draft: Varied as necessary to maintain desired sugar level in pulp.

Diffusion juice samples were analyzed for apparent purity, total ash, invert sugar, and amino nitrogen compounds by the same methods as used for the beet press juice.

Carbonation was simulated by preparing thin juice from diffusion juice in the manner described by Brown and Serro for beets (5). Thin juice samples were analyzed for apparent purity, amino nitrogen compounds, and monosodium glutamate (MSG). The latter was determined by the decarboxylase method (14).

Where samples of cossettes and juices were not analyzed immediately after preparation, they were quick frozen for storage.

The economic evaluation was based on factual values. To facilitate the calculation of realistic figures for growing and processing each variety at each nitrogen fertility level, the sugar content and yield averages were applied to 20,000 acres and an assumed slicing rate of approximately 3500 tons per day. The processor's various agricultural and processing costs used in this study include beet freight, beet receiving expenses, beet labor expense, general agricultural expense, operating supplies and other raw materials, operating labor, maintenance and repairs, local general expense, insurance, taxes, depreciation, and sugar loss in storage. These costs were balanced against returns for salable sugar (corrected for sales expense), molasses, pulp and C.S.F. to establish a processor's earnings for each condition tested.

The grower costs included only the harvesting and delivery and the cost of fertilizer actually removed in the beets, using current fertilizer prices. Other grower costs were deemed too dependent on the type of operation and individual efficiency to be included as fixed costs. It was assumed that the fertilizer content of the beet tops would be returned to the soil.

To estimate sugar losses in storage a special method was developed. It was first assumed that there would be 10 days of direct delivery, which allowed 35,000 tons of beets at no storage loss. The remainder of the beets from 20,000 acres was considered in storage.

The tonnage entering storage was then converted to sugar by applying the sugar content figure. An amount of sugar was calculated to be removed daily from storage which was equivalent to 3500 tons of beets plus a sugar loss in the pile. This procedure continued until the amount of sugar in storage was eliminated.

The daily sugar loss value was taken from Figure 1 which describes the rising losses (as percentage of sugar entering storage) against storage time. These data were plotted from the results of storage tests conducted under conditions considered ideal.

Storage losses calculated in these tests were found to compare favorably with losses under actual conditions calculated by the method of Cottrell (6) for the same acreage.

The final molasses apparent purity was assumed to be 62.0 at a brix of 79.5. This, together with a nominal sugar loss in the process and thin juice apparent purity, provided the data necessary for calculating extraction.

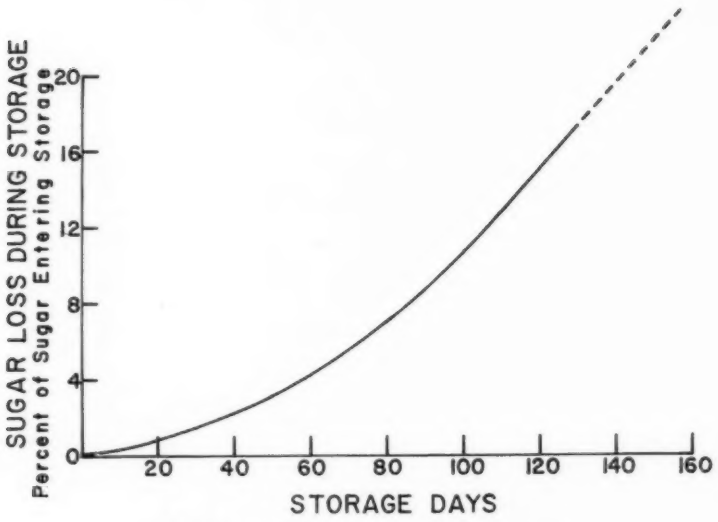


Figure 1.—Daily sugar loss during storage.

Results and Conclusions

Petiole Analysis:

Petiole samples taken at harvest showed highly significant differences for both NO_3 and P_2O_5 concentration (Table 1). For NO_3 the differences were highly significant for both varieties and nitrogen fertility levels whereas differences in P_2O_5 were significant for fertility levels only. Although the variation in P_2O_5 in the petioles was relatively small in comparison to NO_3 concentration, there appeared to be a slight decrease in P_2O_5 as the nitrogen applications were increased.

The generally accepted critical level for NO_3 in the petioles is 1000 P.P.M. and 750 P.P.M. for P_2O_5 (19). On this basis it can be assumed that P_2O_5 was well above the deficiency level for all plots whereas NO_3 was below the deficiency level for the low and medium fertility plots at harvest. The high concentration of NO_3 in the petiole of beets grown on the high level of nitrogen fertility shows that an excess of nitrogen was available to these plots at harvest time.

Percent Sucrose, Yield and Gross Sugar per Acre:

Highly significant differences were found between varieties and nitrogen levels for sucrose percentage, yield of roots, and sugar per acre (Table 2). Since no interactions were found between fertilizer levels and varieties, it is assumed that the varieties performed similarly at each nitrogen level. Although the differences between variety averages, over all nitrogen levels, are significant these differences are small in relation to the differences between fertilizer levels. It is concluded therefore, that nitrogen fertility had a greater effect on sucrose content, yield of roots, and sugar per acre than did the varieties tested.

Beets grown on low nitrogen fertility plots were of high sugar content, but the low root yield resulted in the lowest yield of sugar per acre. In contrast, the roots from the high nitrogen fertility plots had the highest yield, but the reduced sugar content depressed the yield of sugar per acre. The medium level of nitrogen fertility produced a high yield of roots with little reduction in sucrose content which resulted in the highest production of sugar per acre. The fact that the medium level of nitrogen fertility did not result in an appreciable reduction in yield or sucrose content suggests that the available nitrogen was near depletion at or just prior to the time the beets were harvested. Additional evidence from the analysis of NO_3 nitrogen in the petioles at harvest likewise supports this conclusion and which is in agreement with work done by Ulrich (17). In any event, since the yield of roots was near that of the high level plots, it must be assumed that for the major part of the growing season the medium fertility plots had sufficient nitrogen available to support normal growth.

Nonsugars in the Beet:

It is apparent from Table 3 that the amino nitrogen constituents and ash make up a large portion of the total nonsugars present in the beets. The remaining impurities are present in relatively smaller amounts but certain of these are of special importance in the process. For the purposes of sucrose production, invert sugar and raffinose are classed with nonsugars.

The effects of nitrogen fertilization and varieties on the quantities of total nonsugars, amino nitrogen constituents, and ash in the beet are given in Table 3. The concentration of these impurities increased in the beet as the rate of nitrogen application increased. The same marked effects of nitrogen fertilization were noted for concentrations of MSG, total nitrogen, potassium, and sodium. No significant difference was found in invert or

raffinose content due to nitrogen fertility levels, although in the case of the latter there was some difference due to varieties. The effect on P_2O_5 concentration was small although statistically significant.

Table 1.—Variety and Fertilizer Averages for Concentration of NO_3 and P_2O_5 in Petioles at Harvest as Parts Per Million.

Variety	NO_3	P_2O_5
SLC 824	1090	1270
C-51-1	1270	1180
A2-90H0	2050	1270
US22/3	1580	1300
US22S	1410	1170
F54-2H	1860	1390
4323SB	1630	1230
LSD .05	578	N.S.
Nitrogen Levels		
65 lbs./acre	720	1370
140 lbs./acre	700	1210
280 lbs./acre	3240	1200
LSD .05	304	72
.01	403	95
Test Ave.	1560	1260

Table 2.—Variety and Nitrogen Level Averages for Percent Sucrose at Harvest, Yield and Gross Sugar Per Acre.

Variety	Sucrose Percent	Yield Tons/Acre	Gross Sugar Lbs./Acre
SLC 824	16.8	23.1	7780
C-51-1	16.5	26.0	8540
A2-90H0	15.9	24.5	7760
US22/3	15.9	25.5	8080
US22S	16.6	23.6	7820
F54-2H	16.6	25.7	8560
4323SB	16.3	25.0	8140
LSD .05	0.3	1.4	480
.01	0.4	1.9	660
Nitrogen Levels			
65 Lbs./Acre	16.8	20.7	6960
140 Lbs./Acre	16.7	26.4	8820
280 Lbs./Acre	15.6	27.3	8520
LSD .05	0.19	0.7	240
.01	0.25	0.9	320
Test Ave.	16.4	24.8	8100

Table 3.—Variety and Nitrogen Level Averages for Concentrations of Nonsugars in the Beet as Pounds Per Ton of Beets.

Varieties	Total Nonsugars	Amino Nitrogen Constituents	Ash Constituents	Invert Sugar	Total Nitrogen (incl. NO_3)	P_2O_5	Sodium	Potassium	MSG	Raffinose
SLC 824	42.4	17.2	12.0	2.4	2.6	1.4	.294	1.84	3.9	2.0
C-51-1	43.5	16.7	12.9	2.5	2.5	1.5	.324	1.98	3.4	2.1
A2-90H0	42.2	16.4	12.2	2.4	2.5	1.1	.379	1.85	3.0	1.8
US22/3	42.4	16.5	13.6	2.4	2.4	1.4	.441	2.08	3.3	1.9
US22S	43.7	17.0	12.7	2.9	2.6	1.5	.331	1.86	3.6	1.8
F54-2H	40.8	15.4	12.2	2.4	2.4	1.3	.333	1.77	2.8	2.0
4323SB	42.6	16.8	12.9	2.4	2.6	1.3	.379	1.95	3.5	1.7
LSD .05	N.S.	1.0	0.9	N.S.	N.S.	0.14	.043	0.11	0.53	0.23
.01	N.S.	N.S.	1.2	N.S.	N.S.	0.19	.058	0.15	0.71	0.30
Nitrogen Levels										
65 Lbs./Acre	37.5	13.0	11.0	2.5	1.9	1.4	.257	1.74	1.6	2.0
140 Lbs./Acre	40.8	16.0	12.7	2.4	2.4	1.4	.309	1.84	2.8	1.8
280 Lbs./Acre	49.2	20.7	14.3	2.6	3.2	1.3	.497	2.13	5.7	1.9
LSD .05	1.1	0.6	0.6	N.S.	0.09	0.08	.025	0.08	0.25	N.S.
.01	1.4	0.7	0.8	N.S.	0.12	0.10	.033	0.10	0.33	N.S.
Test Ave.	42.5	16.6	12.6	2.5	2.5	1.4	.354	1.90	3.4	1.9

In general, the nitrogen levels caused greater variations in the amounts of nonsugars present in the beets than did the varieties tested. This was particularly evident for total nitrogen and amino nitrogen compounds. For example, in comparing the range in variety averages to the range in fertility level averages (Table 3) for amino nitrogen constituents, it is evident that the effects of nitrogen fertility were greater than varietal effects. The same is true for ash but the differences in ranges are not nearly so striking. Two exceptions to this generalization were raffinose and P_2O_5 content for which varietal effects were greater than fertilizer effects.

Significant interactions of varieties $\times$ nitrogen fertility levels were found for sodium content. The interaction was primarily due to the behavior of variety US 22/3 which had proportionately higher sodium content than the other varieties under high nitrogen fertility. The indicated interaction for MSG as well as for amino nitrogen was primarily the result of variety F54-2H being proportionately lower than the other varieties under high nitrogen fertility, but the interaction F value only approached significance at the .05 level of probability.

The data presented indicate that both varieties and nitrogen fertility levels can appreciably influence the amount of nonsugars present in beets. Excessive nitrogen fertilization is particularly harmful because of the direct effect of nitrogen on the nonsugar constituents as well as sucrose content.

Elimination of Nonsugars in the Process:

For the purpose of evaluating the processing tests, the results were calculated on the basis of sugar rather than tons of beets. Table 4 shows that on this basis the nonsugar load entering the process increased 10.5 percent from the low to medium nitrogen fertility condition and another 31.0 percent from the medium to high nitrogen level. The maximum difference attributable to varieties was 11.2 percent.

In general, as the nonsugar load increased with the nitrogen fertility, the elimination by diffusion also increased, but not proportionately. Elimination by simulated carbonation was generally the same regardless of the amount of nonsugars entering; therefore, the total beet end elimination did not proportionately adjust to increases in the amounts of nonsugars introduced. The amounts and types of nonsugars remaining in the process will determine the sugar and molasses production, upon which the economics of processing sugar beets rests.

There were significant differences in total nonsugars remaining due to varieties.

Table 4.—Total Nonsugars Removed by Diffusion and Carbonation as Pounds Per 100 Sucrose.

	Entering	Removed			Remaining
		Diffusion	Carbonation	Total	
Averages for Varieties, All Nitrogen Levels					
SLC 824	12.0	2.1	4.3	6.4	5.6
C-51-1	12.6	2.6	4.4	7.0	5.6
A2-90H0	12.9	2.5	3.9	6.4	6.5
US22/3	12.8	2.2	4.6	6.8	6.0
US22S	12.5	2.3	4.5	6.8	5.7
F54-2H	11.6	2.2	4.3	6.5	5.1
4323SB	12.5	2.1	4.3	6.4	6.1
LSD .05	1.38	0.43	0.56	0.95	1.06
Averages for Nitrogen Levels, All Varieties					
Low	10.5	2.1	4.3	6.4	4.1
Medium	11.6	2.2	4.3	6.5	5.1
High	15.2	2.6	4.4	7.0	8.2
LSD .05	0.68	0.40	0.27	0.47	1.22

Purity values also reflect the elimination of nonsugars. As shown in Table 5, highly significant differences resulted between varieties and nitrogen fertility levels. These differences appear to be relatively constant for purities shown. As was the case with the nonsugars studied, the effect of nitrogen fertility levels was more pronounced than were varietal effects.

Due primarily to variety F54-2H, a significant variety $\times$ nitrogen level interaction for purity was found (Table 5, thin juice values for varieties at all nitrogen levels). This can be traced to the indicated interaction found in MSG and amino nitrogen constituents already discussed in the section concerning nonsugars in the beet. Variety F54-2H did not show an increased concentration of these nonsugars in proportion to that of other varieties under the high level of nitrogen fertility. The interaction also appeared in total nonsugars entering and remaining in the process (Table 4) but approached significance at the .05 level of probability. Since purity is the ratio of sugar to total dissolved solids (sugar plus nonsugars) expressed as percent, the significant variety $\times$ fertilizer interaction found for purity might be expected.

The amino nitrogen constituents were followed through the process in the same manner as the total nonsugars. Table 6 is a tabulation of the results. The increases in removal of amino nitrogen compounds with the rise in nitrogen fertility levels are

Table 5.—Variety and Nitrogen Level Averages for Purities in Beet Juices with Individual Variety Nitrogen-Level Averages for Thin Juice.

Variety	Beet	Diffusion	Thin
Variety Averages			
SLC 824	89.3	90.9	94.6
C-51-1	88.9	90.9	94.6
A2-90H0	88.6	90.7	94.0
US22/3	88.7	90.5	94.4
US22S	88.8	90.7	94.5
F54-2H	89.6	91.4	95.1
4323SB	88.9	90.7	94.3
LSD .05	0.52	0.51	0.50
.01	0.69	0.68	0.68
Nitrogen Levels			
65 lbs./acre	90.5	92.2	96.0
140 lbs./acre	89.6	91.4	95.1
280 lbs./acre	86.6	88.8	92.4
LSD .05	0.28	0.24	0.23
.01	0.37	0.32	0.30
Test Ave.	89.0	90.8	94.5

Nitrogen Levels, Thin Juice

Variety	65 lbs.	140 lbs.	280 lbs.
SLC 824	96.2	95.1	92.6
C-51-1	96.2	95.2	92.5
A2-90H0	95.8	94.7	91.5
US22/3	95.9	95.3	92.0
US22S	95.9	95.1	92.6
F54-2H	96.3	95.4	93.7
4323SB	95.9	94.8	92.0

LSD .05 between varieties within nitrogen levels = 0.70

significant, but again not proportional to amounts entering. Varieties caused no significant differences in the elimination of these compounds. The variety F54-2H was significantly lower in amounts of amino nitrogen compounds entering the process, which is in accordance with previous comments made on this variety.

Because of its commercial importance, the amino nitrogen compound mono-sodium glutamate was measured in the beets and thin juice. No elimination of this compound was found. This is possibly due to the fact that different methods were used for the determination. Table 7 shows the amounts found in the beet and in thin juice. Nitrogen fertility levels caused significant

differences in MSG whiles differences due to varieties were not significant. Variety F54-2H showed the least amount of MSG.

The following figures based on averages for nitrogen levels, over all varieties, show the relationship of MSG to the total amino nitrogen compounds as measured in thin juice.

Nitrogen Fertility Levels

Low	Medium	High
24.3%	31.9%	42.1%

In these tests the ash constituents were measured in press juice and diffusion juice. Little or no elimination was accomplished by diffusion. The ash content in both the beet and diffusion juice showed significant differences due to nitrogen fertility and varieties (Table 7). The ranges of the averages show that the effects of nitrogen fertility are greater than the effects of varieties.

The invert sugar content of beet and diffusion juice showed a significant rise with the nitrogen fertility level which is also shown in Table 7. There were no significant differences in invert content caused by varieties. The over-all elimination of invert sugar was 0.25 pound per 100 sucrose or 34.2 percent of the average amount entering in the beet.

Table 6.—Amino Nitrogen Compounds Removed by Diffusion and Carbonation as Pounds Per 100 Sucrose.

	Entering	Removed			Remaining
		Diffusion	Carbonation	Total	
Averages for Varieties, All Nitrogen Levels					
SLC 824	4.9	1.2	0.8	2.0	2.9
C-51-1	4.9	1.2	0.9	2.1	2.8
A2-90H0	5.0	1.2	0.8	2.0	3.0
US22/3	5.0	1.2	0.9	2.0	3.0
US22S	4.9	1.2	0.8	1.9	3.0
F54-2H	4.4	1.1	0.8	1.9	2.5
4323SB	4.9	1.2	0.8	1.9	3.0
LSD .05	0.34	N.S.	N.S.	N.S.	N.S.
Averages for Nitrogen Levels, All Varieties					
Low	3.7	1.1	0.7	1.8	1.9
Medium	4.5	1.1	0.8	1.9	2.6
High	6.4	1.3	0.9	2.2	4.2
LSD .05	0.25	0.17	0.11	0.17	0.66

Raffinose content was measured only on beets. It is shown in Table 7 for comparison with other nonsugars when calculated on a sugar basis. As such there were significant differences due to nitrogen fertility levels and varieties. The ranges of differences show that varieties had a greater influence on raffinose content than did nitrogen levels. This was the only constituent measured in which varieties showed a greater influence than nitrogen fertility levels.

Table 7.—Variety and Nitrogen Level Averages for Concentrations of Nonsugars as Pounds Per 100 Sucrose.

	M. S. G.		Ash		Invert		Raffinose
Varieties	Beet	Thin Juice	Beet	Diff. Juice	Beet	Diff. Juice	Beet
SLC 824	1.10	1.05	3.41	3.35	.67	.47	.55
C-51-1	.97	1.05	3.74	3.65	.72	.50	.60
A2-90H0	.90	.98	3.73	3.63	.73	.45	.55
US22/3	.99	1.04	4.10	4.15	.72	.49	.58
US22S	1.04	1.04	3.67	3.53	.84	.53	.51
F54-2H	.79	.86	3.50	3.36	.69	.45	.57
4323SB	1.02	1.10	3.77	3.68	.72	.45	.49
LSD .05		N.S.	0.30	0.29	N.S.	N.S.	.07
.01		N.S.	0.40	0.29	N.S.	N.S.	N.S.
Nitrogen Levels							
65 lbs./acre	.43	.46	3.09	3.10	.69	.45	.55
140 lbs./acre	.81	.84	3.59	3.45	.70	.46	.52
280 lbs./acre	1.74	1.76	4.43	4.32	.79	.53	.57
LSD .05		N.S.	0.30	0.22	N.S.	N.S.	.07
.01		0.15	0.23	0.17	.09	.06	N.S.
Test Ave.	0.98	1.02	3.70	3.62	.73	.48	.55

Extraction:

Those nonsugars which remain in the juice after carbonation will enter the crystallization phase of the process, and as a group will depress the crystallization rate of the associated sucrose to the point where it becomes impossible to further extract sucrose economically by crystallization. At this stage the product is molasses, not sugar. Net extraction is the ratio of salable white sugar produced to the total amount of sugar entering the process, expressed as percentage. It is actually an efficiency figure for the processing of sugar beets and as such is of prime importance to the economics of sugar processing.

Table 8 lists the net extraction figures calculated from the results of these tests (see Methods and Materials). Varieties caused no significant differences but every rising step in the nitrogen fertility level caused a significant drop in net extraction.

Table 8.—Percent Extraction.

Variety	Low	Medium	High	Variety Average
SLC 824	91.9	90.0	85.3	89.1
C-51-1	91.9	90.0	85.1	89.0
A2-90H0	91.2	89.1	84.7	88.3
US22/3	91.3	90.2	84.0	88.5
US22S	91.4	90.0	85.3	88.9
F54-2H	92.1	90.4	87.3	89.9
4323SB	91.4	89.4	84.1	88.3
N level Ave.	91.6	89.9	85.1	88.9

LSD .05 between variety averages = 1.7

LSD .05 between nitrogen level averages = 0.9

It is of interest to note that although it is not significant at the 5 percent level, the variety F54-2H led all other varieties tested in net extraction at each nitrogen fertility level. The ranges of averages show that the influence on extraction by nitrogen fertility levels was far greater than by varieties in these tests.

Production of Sugar, Molasses and MSG.

Also of prime importance to the economics of the industry is the over-all production of sugar, molasses, and concentrated Steffens filtrate resulting from the growing and processing operations. Table 9 is a compilation of this information as calculated from the results of these tests. This tabulation again shows the tremendous effect of nitrogen fertility levels on both sugar and byproducts, while varieties show significant differences on the gross sugar and salable sugar. It is of interest to note in this case that each variety occupies the same position in production of gross sugar and salable sugar.

Correlations:

The correlation coefficients (Table 10) show a definite interrelationship among all the variables correlated with the exception of raffinose which was significantly correlated only with sodium. Amino nitrogen constituents, MSG, and total nitrogen appeared to show a higher degree of association with purity than sucrose percentage, although percent sucrose was highly correlated with purity. Also they gave correlation coefficients equal to or higher than percent sucrose with extraction but of opposite sign. In addition, the correlations of ash with percent sucrose, purity and extraction were lower than for nitrogen constituents.

Table 9.—Sugar and Byproduct Production Averages for Variety and Nitrogen Level Before and After Processing as Pounds Per Acre.

	Entering		Leaving			
Variety	Gross Sugar	Non-Sugars	Salable Sugar	Molasses	CSF Solids	MSG
SLC 824	7780	994	6596	1395	422	89
C-51-1	8540	1144	7174	1517	459	97
A2-90H0	7760	1046	6503	1483	475	82
US22/3	8080	1099	6740	1494	452	92
US22S	7820	1035	6619	1427	432	88
F54-2H	8560	1053	7256	1359	411	79
4323SB	8140	1075	6809	1557	469	97
LSD .05	480	N.S.	666	N.S.	N.S.	N.S.
Nitrogen Levels						
65 lbs./acre	6960	771	6144	900	271	34
140 lbs./acre	8820	1074	7482	1394	422	78
280 lbs./acre	8520	1347	6815	2091	644	156
LSD .05	240	176	764	272	86	42
Test Ave.	8100	1064	6814	1462	446	89

In brief, the nitrogen and nitrogen compounds in the beets appear to be the most closely associated with quality factors of any of the beet constituents measured in this study.

Of interest also were the significant correlations found between NO_3 in the petioles and nonsugars constituents in the roots. NO_3 in the petioles showed as strong a negative association with percent sucrose as did the nitrogen compounds in the roots.

Economic Appraisal:

This section is an attempt to evaluate the effects of nitrogen fertility and varietal differences by the most critical indicator of all—that of profit.

The influence of nitrogen fertility level and the individual varieties chosen on the economics of growing and processing sugar beets in this test is shown by the dollar return index values in Table 11. This table shows that the medium nitrogen fertility level was the most beneficial for both grower and processor for all varieties tested. The high nitrogen condition was more profitable than the low. Of the varieties tested, F54-2H and C-51-1 showed the greatest profit possibilities for both grower and processor considering all nitrogen levels tested, while, as would be expected, the inbred A2-90H0 offered the least return.

These figures show that the influence of the individual varieties on the economics of the combined operations was less than

Table 10.—Correlation Coefficients Among 12 Variables Determined from Individual Plot Values. Where Applicable, Values Obtained for Concentrations in the Beet Were Used to Compute r Values.

Variables	Sucrose	Purity	Nonsugar	Ash	Amino N	MSG	Total N	Raffinose	Sodium	Potassium	NO_3 in Pet.
% Sucrose	—										
Purity	.68	—									
Total non-sugars	—.57	—.96	—								
Ash	—.46	—.65	.63	—							
Amino N	—.52	—.89	.91	.62	—						
MSG (Thin Juice)	—.58	—.89	.88	.59	.89	—					
Total N	—.56	—.87	.88	.64	.92	.89	—				
Raffinose	.09	.11	—.14	—.11	—.18	—.15	—.19	—			
Sodium	—.66	—.78	.74	.59	.73	.70	.70	—.29	—		
Potassium	—.47	—.58	.54	.55	.53	.53	.52	—.03	.49	—	
NO_3 in Petioles	—.64	—.67	.61	.42	.60	.64	.64	.06	.51	.44	—
Extraction	.75	.88	—.73	—.56	—.72	—.76	—.73	.04	—.69	—.55	—.66

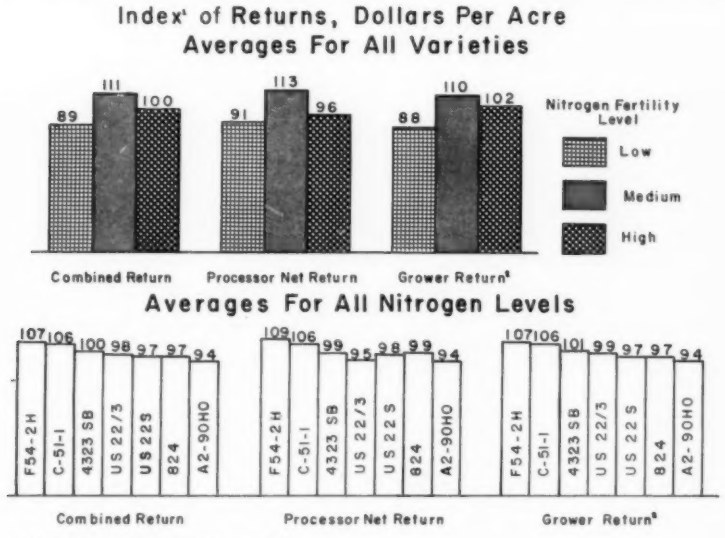
r = .16 for significance at .05

r = .20 for significance at .01

that of the nitrogen fertility levels. This is exemplified in Table 11 for combined returns where nitrogen fertility levels was responsible for a 22 percent range from the over-all test average while varietal differences caused only 13 percent range in these returns. This provides a total of 35 percent variation from the lowest to highest fertility-variety combination. Figure 2 is a graphic representation of the data of Table 11.

Table 11.—Index Figures for Variety and Nitrogen Level Averages.

Variety	Combined Return	Grower Return	Processor Net Return
SLC 824	97	97	99
C-51-1	106	106	106
A2-90H0	94	94	94
US22/3	98	99	95
US22S	97	97	98
F54-2H	107	107	109
4323SB	100	101	99
Nitrogen Levels			
65 lbs./acre	89	88	91
140 lbs./acre	111	110	113
280 lbs./acre	100	102	96
Test Average	100	100	100



[1] Overall test average set at 100.
[2] Less costs of fertilizer and harvesting.

Figure 2.—Variety and nitrogen level averages.

The most profitable combination of variety and fertilizer level for both processor and grower was the variety F54-2H grown on the medium level of nitrogen fertility. This combination resulted in an increase in combined returns of 18 percent over the entire test average.

Discussion

The effects of nitrogen fertilization on the economics of sugar production and extraction were more pronounced than the effects of the varieties tested. This was the result of the greater effect of nitrogen fertilization on yield, percent sucrose, and nonsugar content.

The most profitable level of nitrogen fertilization for grower and processor was the medium level which produced the maximum gross sugar and salable sugar per acre. The low nitrogen fertility level effected a low root yield which resulted in the lowest gross sugar in spite of the high sugar content and thus depressed the production of salable sugar and byproducts. The high nitrogen application resulted in the highest root yield, but the gross sugar was depressed by the low sugar content. The accompanying nonsugars in this case caused a reduced net extraction and thus lowered the salable sugar but produced the highest yield of byproducts.

The results of the economic appraisal pointed out the overwhelming influence of salable sugar on the economy of the industry in comparison with the byproducts and signalled the impossibility of regaining from the byproducts what is lost through reduced extraction.

The association of total nitrogen and nitrogen compounds with reduced purity and extraction in the roots was pronounced. This raises the question as to whether the nitrogen compounds *per se* cause a direct reduction in purity and net extraction through their melassigenic power or whether it is the result of the melassigenic power of other nonsugars associated with the nitrogen constituents. Considering the work of Rorabaugh and Norman (13) and Haddock et al (11) and the increased nonsugars accompanying increased nitrogen fertilization in this study, it appears that both conditions are probably factors influencing purity and net extraction. If both the nitrogen constituents and the other nonsugars increase in the beet with increased nitrogen fertilization, the crystallization process is bound to be affected. In this study the relative importance of individual nonsugars to the rate of crystallization has not been considered, but consideration of this factor could only make the case for high nitrogen fertilization worse than has been shown by these results.

Having a wide range of nitrogen fertilization as well as different varieties in the test produced a wide variation in the concentration of nitrogen compounds in the beets. This made it possible to obtain correlation coefficients of variables affected by a wide range of conditions. As a result, the r values obtained in this study may vary from those obtained by other workers studying primarily varietal variations.

There was evidence in this study of interactions of varieties and fertilizer levels in regard to correlations. For instance, ash increased with nitrogen fertilization as did the amino N constituents resulting in a highly significant r value between ash and amino N. On the other hand, the varieties high in amino N were not necessarily high in ash (Table 3).

In the case of raffinose, variation was due primarily to varieties rather than to the effects of nitrogen fertilization as was the case with other nonsugars. This may partially explain the low correlation coefficients obtained with raffinose vs. other nonsugars.

Although other factors of climate and soil undoubtedly affect quality and production of sugar beets, nitrogen fertility is so critical that every effort should be made to apply near "optimum" amounts of nitrogen to the commercial beet crop. The "optimum" level may be defined as that level of nitrogen fertilization beyond which increases in yield are not sufficient to justify the cost of additional nitrogen applied, and the losses due to reduced sucrose percentages and net extractions are not significant. To be able to determine such a level for a particular field prior to planting is a near impossible task because of the factors that influence the nitrogen requirements such as irrigation practices and seasonal differences. However, through the aid of cropping histories, fertilizer histories, and soil tests, control of high or low nitrogen fertilization applications is practicable and should be achieved.

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Gibberellic Acid Effects on Seed and Seedlings of Sugar Beets

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Gibberellic acid, a plant growth regulator produced by the fungus *Giberella fujikuroi,* has been tested on a wide variety of agronomic, horticultural, and forest plants during the past two years. Growth response has been varied—some plants have responded to minute quantities of the acid, and others with heavy dosages have showed lesser response. Marth et al (1)[2] states "Elongation of seed stocks of beet plants was stimulated but it is not known at this time whether seed production was accelerated." Gaskill (2) has reported that reproductive development was hastened in one variety of sugar beets.

The experimental results reported in this paper are from a series of greenhouse tests of seed treatments, foliage sprays, and soil applications, for the purpose of determining in some measure, the value of this chemical in the sugar beet crop.

Materials and Methods

The experimental work herein reported can be divided into four sections: (A) Seed soak and cotyledon treatments, (B) Seed soak and cold germination treatments, (C) Dust and seed soak treatments and, (D) Variety and treatment tests. A monogerm hybrid, 108 MS mm x 308 inbred, was used for the first two tests. SLC No. 15 (a monogerm) was used for (C) experiments. American Crystal variety American No. 3 S, and the U.S.D.A. variety NB1 were used for the (D) test. Greenhouse pots of 4-inch size were used for (A), (B), and (D) tests. The (C) test was in greenhouse flats. Since the (D) test included soil treatments, pots were lined with light polyethelene plastic so that none of this type of treatment would drain from the pots. The greenhouse soil used was rather sandy in type. Test (C) had three replications per treatment (greenhouse flats) and test (D) had three replications (pots) per treatment.

In test (D) both varieties were given 30 days of photo-thermal induction (continuous light at 45° F.) in comparison with no photo-thermal induction. Commercial fertilizer as ammonium phosphate was applied twice during the five-month growing season to each pot in amounts of approximately 100 pounds per acre. A complete nutrient solution was applied once to all pots. Artificial light was used continuously throughout the growing season.

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[1] Plant Breeder, Agricultural Research Station, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

Experimental quantities of gibberellic acid obtained from Eli Lilly and Company were used for the (A) and (B) tests; "Gibrel," obtained from Merck and Company was used for the (C) test, and "Brellin" obtained from S. B. Penick and Company was used for the (D) test.

All seed soak treatments reported are from a four-hour soak.

Experimental Results

(A) Seed Soak and Cotyledon Treatment Results.

The treatments used in this test were as follows:

Seed Treatment (four hour soak)	Cotyledon Treatment (drops applied to the growing tip)
Gibberellic Acid, 10 p.p.m.	10 p.p.m. once
Gibberellic Acid, 10 p.p.m.	10 p.p.m. twice
Gibberellic Acid, 10 p.p.m.	100 p.p.m. once
Gibberellic Acid, 10 p.p.m.	100 p.p.m. twice
Gibberellic Acid, 100 p.p.m.	10 p.p.m. once
Gibberellic Acid, 100 p.p.m.	10 p.p.m. twice
Gibberellic Acid, 100 p.p.m.	100 p.p.m. once
Gibberellic Acid, 100 p.p.m.	100 p.p.m. twice
Water Soak	100 p.p.m. once
Water Soak	No Treatment

At the end of four weeks, slight elongation of stem had occurred where the 100 p.p.m. cotyledon treatment had been made once and twice on all the seed treatments. There appeared to be very little difference between the 100 p.p.m. cotyledon treatments once and twice. The water soaked check, treated once with 100 p.p.m. was approximately the same in stem elongation as the other 100 p.p.m. cotyledon treatments. No visible effect was obtained from any of the 10 p.p.m. treatments.

(B) Seed Soak and Cold Germination Results.

In this test 400 seeds were soaked for four hours in 100 p.p.m. gibberellic acid and placed on germination trays, along with a check of distilled water soak. The trays were allowed to germinate at 72° F. until approximately three-fourths of the seed had sprouted, at which time the trays were placed in a cold chamber at 39° F. for 24 hours and lowered one degree each 24 hours until 32° was obtained. At this temperature freezing occurred, and the two trays were removed after six hours. Forty of the longest sprouts from each tray were planted in the greenhouse. The results were negative. At the end of six weeks no evidence of stem elongation or of bolting was seen in either the gibberellic acid or the water soak treatment.

(C) Dust and Seed Soak Treatment Test.

Due to the lack of stimulation from seed treatment at concentrations of 10 and 100 p.p.m., it was decided to use for this test, dust treatments of 1000 p.p.m., with talc, and with the seed protectant Orthocide; and to use 100 and 1000 p.p.m. as soak treatments. Three flats were planted with 100 seeds each of the treatments and checks, and placed at random in the greenhouse. The germination results of this test are given in Table 1.

Table 1.—Greenhouse Germination Results from Dust and Soak Treatments.

	Percent Germination (8 Days)
Dust Treatment	
Orthocide—alone	80.0
Talc—alone	82.3
Orthocide + 1000 p.p.m. gibberellic acid	82.3
Talc + 1000 p.p.m. gibberellic acid	80.0
Check—no treatment	82.0
F. value	.24 Non-significant
4 Hour Soak Treatment	
100 p.p.m. gibberellic acid	82.3
1000 p.p.m. gibberellic acid	80.0
Check—distilled water	80.0
F. value	.37 Non-significant

(D) Variety and Treatment Test Results.

Since growth stimulation had not been obtained with seed treatment nor on foliage at dilutions of 10 p.p.m., and only slight effects with 100 p.p.m. on foliage, it was decided to conduct a test using only 1000 p.p.m. on two varieties—a fast bolting variety American No. 3 S and a slow bolting variety NB1, both with and without photo-thermal induction. Five gibberellic acid treatments were set up as follows: one foliage spray, three foliage sprays, 5, 10, and 25 ml. applied to the soil, along with a no treatment check. Three four-inch pots with three plants each were used for each treatment. The pots were lined with light polyethelene plastic and approximately 6.5 cubic inches of soil placed in each pot.

When the second true leaves were beginning to appear, the plants in the 36 pots not receiving thermal induction were treated with gibberellic acid, and the remaining 36 pots were placed in a photo-thermal room at 45° F. for 30 days. The three spray treatment for the plants not receiving thermal induction was sprayed on at 10-day intervals. All the soil applications were made at one time. At the end of 30 days the thermally induced

plants were treated using the same procedure as used for the plants not thermally induced.

Some difficulties were experienced in the application of the 15 and 25 ml. quantities of acid to the soil; as wilting was obtained with both these treatments and with the 25 ml. treatment some plants died. In 10 days after treatment however, these heavy soil treatments showed definite growth stimulation to the plants of American No. 3 S, and to a lesser degree to NB1. Final measurement of stem elongation was made five months after the experiment was started, on both non and thermally induced plants of both varieties, at which time it was considered that growth stimulation was complete.

This test had been planned to determine if bolting could be induced by use of gibberellic acid with or without partial thermal induction. Only three plants in American No. 3 S thermally induced produced normal seed stalks and flowers. One was in the three spray treatment, one in the five ml. treatment and one in the non treatment check. Since one bolter had appeared in the non treated check it could not be assumed that the other two bolters were due to gibberellic acid treatments. Further, every plant of both varieties, in both the thermal and non thermal induction and for the 15 and 25 ml. soil application, showed no sign of a bud at the end of the elongated stem. After stem elongation was complete on these plants new leaves appeared to be normal.

Table 2.—Stem Elongation Effect of Gibberellic Acid Treatments on Sugar Beet Seedlings.

Treatment				Treatment			
Variety	Gibberellic Acid' 1000 p.p.m.	Photo Thermally Induced	Stem Elongation Inches	Variety	Gibberellic Acid 1000 p.p.m.	Photo Thermally Induced	Stem Elongation Inches
Am. No. 3 S	Spray 1	None	.68	NB1	Spray 1	None	.60
Am. No. 3 S	Spray 3	None	1.27	NB1	Spray 3	None	.95
Am. No. 3 S	Soil 5 ml.	None	1.09	NB1	Soil 5 ml.	None	.70
Am. No. 3 S	Soil 15 ml.	None	1.43	NB1	Soil 15 ml.	None	1.45
Am. No. 3 S	Soil 25 ml.	None	5.38	NB1	Soil 25 ml.	None	1.52
Am. No. 3 S	Check	None	.59	NB1	Check	None	.52
Am. No. 3 S	Spray 1	30 Days	.66	NB1	Spray 1	30 Days	.41
Am. No. 3 S	Spray 3	30 Days	1.06	NB1	Spray 3	30 Days	.77
Am. No. 3 S	Soil 5 ml.	30 Days	1.37	NB1	Soil 5 ml.	30 Days	.57
Am. No. 3 S	Soil 15 ml.	30 Days	2.16	NB1	Soil 15 ml.	30 Days	.90
Am. No. 3 S	Soil 25 ml.	30 Days	7.84	NB1	Soil 25 ml.	30 Days	1.34
Am. No. 3 S	Check	30 Days	.54	NB1	Check	30 Days	.43

Stem elongation data (Table 2) were obtained by measuring each stem or crown from the cotyledon scar to the growing tip of the stem or crown. Data were averaged by pot, with the three pots per treatment used as replications. The three plants which had bolted and flowered were not measured. Statistical analysis of the data is given in Table 3.

Table 3.—Analysis of Variance.

Variation	D.F.	Sum Squares	Mean Squares	F. Value
Total	71	23,886.73		
Replications (pots)	2	330.65	165.33	NS
Varieties	1	2,468.70	2,468.70	20.45*
Error (A)	2	241.41	120.71	
Climates[1]	1	38.43	38.43	NS
Climates x varieties	1	247.16	247.16	16.47*
Error (B)	4	60.05	15.01	
Treatment	5	10,595.49	2,119.09	26.64**
Treatment x varieties	5	6,009.38	1,201.88	15.11**
Treatment x climate	5	340.75	68.15	NS
Treat. x var. x climate	5	372.43	74.49	NS
Error (C)	40	3,182.28	79.56	

[1] Photo-thermal induction versus none.

From these results it is evident that growth stimulation was greater in American No. 3 S than in NB1, and that American No. 3 S did react somewhat differently than NB1 in different "climates." The comparison of "climates" as an average for both varieties showed a non-significant difference. It would appear therefore, that 30 days in photo-thermal induction was not enough to overcome dormancy, and none of the gibberellic treatments were effective in causing true bolting and flowering in either variety. The greatest differences obtained in this test were between treatments. The varieties also reacted differently to the different treatments.

Discussion

From the results obtained in this series of experiments it appears evident that the sugar beet requires heavy dosages of gibberellic acid for effective growth stimulation. It also appears that excessive application can cause stimulation which causes abnormal apical growth (see Figure 1). The lack of bolting in these tests is rather surprising. Previous work with American No. 3 S has indicated that 60 days in induction temperature is enough to cause nearly all plants of this variety to bolt. Heavy soil dosages of 1000 p.p.m. gibberellic acid (15 and 25 ml. per 6.5 cubic inches of soil) did not produce bolting in this variety with 30-days induction.

Figure 1.—American No. 3 S photo-thermally induced for 30 days at 45° F. Left: Soil application of 25 ml. of 1000 p.p.m. "Brellin." Right: No treatment check.

The varieties differed greatly in their growth response, but in so far as bolting stimulation is concerned the data obtained do not show any indication that dormancy could be overcome by the use of 30 day photo-thermal induction and gibberellic acid treatment on either variety. If such results are generally obtained, the value of this chemical may be limited to increasing the growth of plants following thermal induction for any benefit which might be obtained from increased seed production or other characters.

All seed treatment tests reported in this paper have given negative results. This applies to dust treatments at 1000 p.p.m. and four hours seed soak treatments at 10, 100, and 1000 p.p.m. It would be expected, however, that stimulation of some sort would occur if seed were sprouted in 1000 p.p.m. gibberellic acid media. However, continued application would have to be made to the soil at intervals and with a probable result similar to that obtained from the heavy soil applications as reported in this paper.

Summary

1. Four hour seed soak treatments of 10, 100 and 1000 p.p.m. gave no indication of any growth stimulation at emergence or later, in greenhouse experiments. Dust treatments at 1000 p.p.m. also gave negative results.

2. Gibberellic seed soak in 100 p.p.m. for four hours, germinated, and then "hardened off" in a cold chamber for 8 days, did not cause stem elongation or bolting when the plants were grown in the greenhouse.

3. Using stem elongation measurements after a five-month growing period in four-inch pots, two varieties were strikingly different in their response to 1000 p.p.m. gibberellic acid treatments, with one variety reacting in a different manner than the other from a different growth "climate."

4. Heavy treatments (1000 p.p.m.) gave greater stem elongation than light treatments, with one variety reacting in a slightly different manner than the other to the various treatments.

5. Thirty day's thermal induction followed by varying dosages of gibberellic acid failed to induce normal bolting.

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Successive Annual Backcrosses to a Nonbolting Inbred Line of Sugar Beets

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By rigid selection, Munerati (4)[2] developed an extremely fast-bolting annual beet. Abegg (1) confirmed Munerati's conclusions that this annual beet carried a major dominant gene for annualness, plus accessory genes which increase the rate of bolting. Owen (5) made use of an annual male-sterile beet as a rapid means of obtaining information regarding potentialities for pollen restoring ability of different biennial pollinators. Finally the idea was advanced (6) of developing uniform isogenic annual lines of sugar beets to speed up practical backcross operations. Preliminary work soon showed that hybrids produced by crossing annuals to bolting-resistant biennials are slower to initiate seedstalks than hybrids between annuals and easy-bolting biennials. Beets bred for winter plantings in California represent an extreme degree of bolting resistance. A successful annual backcross procedure with these highly selected bolting-resistant lines provides a challenge and a severe test of the idea of controlling reproductive development in beets by the action of a single Mendelian factor.

Isogenic lines of annual beets also open up opportunities for new physiological investigations. A very uniform slow-bolting annual population from a fourth generation backcross provided favorable material to study the effects of gibberellic acid treatment on reproductive development without recourse to thermal induction.

Material and Methods

An annual beet several hybrid generations removed from Munerati's annual, backcrossed twice to the curly-top-resistant line CT9 (8), furnished the gene *B* (1) for bolting or annual growth habit. The bolting-resistant self-fertile inbred NB1 (3) was hybridized with the annual. This hybridization was facilitated by use of the gene *a* for abortion of pollen (6), otherwise known as Mendelian male sterility. The gene *R* for red hypocotyl color, known to be linked to the gene *B* (1), was used as a seedling marker. The cross was made by covering the inflorescences with paper bags and applying pollen from NB1 (*bb rr AA*) to a male-sterile annual of constitution *BB RR aa*. This hybrid was slower to bolt than other annuals but it flowered normally and was self-pollinated in a warm greenhouse. An F_2

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[2] Numbers in parentheses refer to literature cited.

population, obtained by selfing an F_1 beet, segregated for all three genes. A selected F_2 male-sterile beet, whose breeding behavior showed it to be of constitution *Bb Rr aa*, was backcrossed to NB1 in 1954. Additional generations were obtained in 1955, 1956 and 1957. The inbred NB1 did not segregate for the recessive gene *a*, therefore, an extra advanced generation between backcrosses was necessary for recovery of male-sterile *aa* segregates.

Segregating populations were grown in the greenhouse in an environment designed to provide photo-induction without thermal induction (7). During the summer months the greenhouse temperatures were often in excess of 100° F. Long photoperiods, 18 hours to continuous illumination, provided the necessary photo-induction.

Experimental Results

Segregating Populations

Data for the b_1, b_3, and F_2b_3 generations from a cross between an annual beet and the bolting-resistant NB1 inbred are shown in Table 1. The good over-all 1:1 backcross ratio and 3:1 F_2 ratio for annual and vegetative biennial beets indicate the operation of a single gene for annualness. The relatively close linkage between genes *B* and *R* confirms previous findings (1 and 9). In the 1954-55 tests at Salinas, California, and Salt Lake City, Utah, the beets were grown during the winter months. At Salt Lake City the planting was made September 23 and at Salinas on November 1.

At Salinas, night temperatures ranged between 40 and 50° F., with a maximum day temperature of approximately 70° F. Photo-induction was encouraged by artificial light supplied between 9 p.m. and 4 a.m. to lengthen the photoperiod. Under this environment one would not expect seedstalk development with the bolting-resistant parental line NB1 but bolting could be expected with some easy-bolting types of biennial beets. Here the eight beets classified as annual were fully reproductive and in full flower by March 18. The seven beets classified as vegetative remained permanently vegetative during the summer.

At Salt Lake City the winter greenhouse temperatures were somewhat warmer and the beets were allowed to remain under a short photoperiod until January 20 when continuous illumination was supplied. The first annual beets flowered April 7 and the latest individuals began flowering May 2. In spite of this irregular bolting all annual segregates were fully reproductive (Figure 1). Classification into the two groups, annual and vegetative, was therefore entirely clear-cut and decisive, although

Figure 1.—Twelve representative beets from the first backcross, annual *Bb Rr* × biennial *bb rr*. To the right are six dominant red hypocotyl *R* segregates, the majority of which bolted because of linkage between genes *B* and *R*. To the left are six recessive *rr* segregates, the majority of which remained vegetative.

Photographed at Salt Lake City, Utah, April 6, 1955.

in some instances there were noticeable variations in rate of bolting.

Another planting at Salt Lake City was made June 10, 1955, with final classification August 1. During this period maximum greenhouse temperatures were often in excess of 100° F. with no chance whatever for thermal induction. The planting was made in greenhouse beds with approximately ten beets in a 30-inch row and eight inches between rows. Here the growth was relatively uniform and seedstalks of annual segregates developed more uniformly than in previous tests. Annual segregates were pulled and discarded August 1 when all bolting appeared to be complete and the most advanced individuals were in the early bud stage. Vegetative segregates allowed to grow an additional 30 days showed no increase in bolting.

A second backcross generation was produced in 1955, and in 1956 six progenies of the third backcross were obtained. Seed of these six progenies was planted in greenhouse beds July 5, 1956. Because of some irregularity in bolting, partly accounted for by irregularity in the artificial illumination to lengthen the photoperiod, final classifications were delayed until November 19. By this time the majority of the bolters had produced ripe

seed and all bolting appeared to be complete. Evidence was obtained from one of the six progenies (Table 1) that crossing over had taken place between genes *B* and *R* in the previous generation. This resulted in repulsion rather than coupling for progeny 64479 (Table 1).

Table 1.—Data for the Backcross and F_2b_2 Generations from a Cross Between the Bolting-Resistant Inbred *bb rr* and the Heterozygous Annual *Bb Rr*.

Location of Test	Planting Date	Progeny Number	Classification of Offspring: Number of Beets: Bolters *BR*	Bolters *Br*	Vegetative *bR*	Vegetative *br*	Total	Percent Recombinations
First Backcross Generation								
Salinas, Calif.	11/1/55	44558	7	1	2	5	15	
Salt Lake City, Utah	9/23/54	44558	32	4	7	30	73	
	6/10/55	44558	26	3	3	27	59	
		Sub-total	65	8	12	62	147	13.6
Third Backcross Generation, Coupling								
Salt Lake City, Utah	7/5/56	64472	20	2	5	31	58	12.1
Salt Lake City, Utah	7/5/56	64473	36	7	3	22	68	14.7
Salt Lake City, Utah	7/5/56	64475	21	1	2	20	44	6.8
Salt Lake City, Utah	7/5/56	64478	18	1	3	16	38	10.5
Salt Lake City, Utah	7/5/56	64480	44	7	6	45	102	12.7
		Sub-total	139	18	19	134	310	11.9
Third Backcross Generation, Repulsion								
Salt Lake City, Utah	7/5/56	64479	3	32	32	4	71	9.0
		TOTAL—BOTH GENERATIONS					528	12.1
F_2 of the Third Backcross Generation								
Salinas, Calif.	11/28/56	64514	88	11	11	16	126	20.7
Salinas, Calif.	11/28/56	64515	102	16	9	24	151	18.5
	Total—both F_2 progenies		190	27	20	40	277	19.5

Two progenies of the F_2b_2 generation were planted in the greenhouse at Salinas, California, on November 28, 1956. The plants were grown in individual aluminum foil cylinders approximately three inches in diameter and 3½ inches deep. From November through March greenhouse temperatures ranged between 60 and 70° F. at night and 70 and 85° F. during the day. Heat was turned off April 1 and night temepratures occasionally dropped to 55° F. during April and May. Day temperatures frequently reached 85 to 95° F. during the spring months. Artificial light was furnished from 9 p.m. to 5 a.m. during the entire growing period.

Bolting was irregular in both progenies. Flowering started on February 11 and continued until May 27, 1957. The plants which bolted were fully reproductive and were definitely annuals. A clear-cut 3:1 ratio of bolters to vegetative plants occurred in both progenies (Table 1).

Selection for Slow Bolting Annuals

In the 1956 summer greenhouse planting at Salt Lake City in the b_3 backcross to NB1, population 64473 (Table 1), bolting was observed to be slower than in the other four sister populations. The bolting was also more irregular. Two of the slowest bolters in this population were selected for further study. By September 12 these two selected plants had barely started to initiate seedstalks. During the next three months at cool temperatures they made a vegetative trotzer-like growth. In early March of 1957 under warmer temperatures and continuous illumination, these two plants became reproductive and self-pollinated seed was obtained from them. Seed from one of these extremely slow-bolting beets (population 74472) was planted back to greenhouse beds at Salt Lake City on May 30, 1957.

The new generation was grown under the relatively high summer greenhouse temperatures with photo-induction aided by continuous illumination. By July 25, 1957, the bolting of most other lines in the same planting date were either completed or well under way but there was no sign of bolting in population 74472. The bolting of two unselected fourth generation backcrosses to NB1 was well under way even by July 25. From the total of 58 plants in population 74472 one bolter appeared on August 4. By August 18 there were 17 bolters. Finally by September 12, when it was necessary to discontinue the experiment, there were 28 bolters. Some of these bolters were extremely slow and again two more of the slowest were maintained for further genetic study.

It should be remembered that the slow-bolting beets selected in 1956 in the third backcross, population 64473, were shown to be of constitution *Bb Rr Aa* from their breeding behavior. Population 74472 was obtained by selfing one of these triple heterozygotes. The new generation is indicated by the designation F_2b_3. Seedling beets of population 74472 segregated as expected for hypocotyl color, with approximately 75 percent *R* hypocotyl to 25 percent *rr* recessive. In the four-leaf stage the plants were thinned allowing about ten seedlings per 30-inch row. Half of the rows were thinned to *R* seedlings and half to *rr* to permit more direct comparison of the linkage effect between genes *B* and *R*. On final classification September 12, with the total of 58 plants and 28 bolters, the phenotypic counts were as

follows: 24 *BR*, 4 *Br*, 4 *bR*, and 26 *br*. The method of thinning to equal numbers of plants for each hypocotyl color, instead of to the original 3:1 ratio, complicates some of the calculations. Assuming ten percent crossing over between genes *B* and *R* and considering the observed 28:30 ratio for hypocotyl color, expected results would be 26.1 *BR*, 5.7 *Br*, 1.8 *bR* and 24.3 *br*, which is in close agreement with observed results. Therefore, in spite of the extremely slow bolting in the F_2b_3 population 74472, the results indicate that the single gene *B* for annual growth habit still operates to produce reproductive development under high temperatures by means of photo-induction alone without recourse to thermal induction. It must be assumed that accessory genes influenced the rate of bolting.

Effect of Gibberellic Acid in the Fourth Generation Backcross

Data presented thus far have dealt with backcross populations segregating for the gene *B* for annual growth habit and the gene *R* for red hypocotyl color. For certain experiments there is an advantage in avoiding this type of segregation. The method of backcrossing to the inbred NB1 (*bb rr AA*) involves alternate generations of selfing to recover Mendelian male-sterile recessive *aa* segregates. After selfing triple heterozygotes *Bb Rr Aa* from the successive backcrosses, the chances of recovering homozygosity versus heterozygosity for one dominant gene follows the ratio of 1:2. With the gene *R* for red hypocotyl color, which is considered first because its expression is quickly revealed in the cotyledon stage, one may expect 1 *RR*: 2 *Rr* segregates. These two genotypic classes, after roguing to *aa* Mendelian male-sterile recessives, were crossed at random to the recurrent parent *bb rr AA*. In these backcross populations, germination tests quickly reveal the nature of the female parentage as far as the gene *R* for red hypocotyl color is concerned. Backcross populations derived from *RR* × *rr* hybrids produce 100 percent *Rr* red hypocotyl offspring, whereas *Rr* × *rr* hybrids produce 50 percent *rr* recessives which lack the red pigment. It was expected that homozygous *RR* annual segregates, obtained after selfing triple heterozygotes, would most frequently be of constitution *BB RR* because of the close linkage between genes *B* and *R*. A fourth generation backcross, population 74482, was obtained in 1957 which on germination was completely uniform for red hypocotyl color, and after final investigation was found to be completely annual but slow in rate of bolting. The uniformity in population 74482 made it a highly desirable population for the study of the effect of gibberellic acid treatment on reproductive development of slow-bolting annual beets.

On May 30, 1957, seed of the population 74482 was planted in greenhouse beds at Salt Lake City. A solution of gibberellic acid (250 p.p.m.) was sprayed on these beets at weekly intervals. The plants were grown under continuous illumination at the prevailing high greenhouse temperatures, which were considerably higher than outside temperatures. There was a great difference in rapidity of seedstalk initiation and rate and uniformity of bolting in favor of the plants receiving the gibberellic acid treatment. By July 23, or 54 days after planting, all of the 79 plants in population 74482 treated with gibberellic acid had initiated seedstalks whereas only 70 percent from a total of 80 plants in the same population had initiated seedstalks without the gibberellic acid treatment. There was complete bolting in an untreated portion of the population by August 11, or 73 days after planting. Final conclusions regarding classification as to annual or biennial phenotypic classes were not affected, therefore, by the gibberellic acid treatment, but the treatment did materially increase the rate of seedstalk initiation and reproductive development of these slow-bolting annual beets. More details, including effects of gibberellic acid treatment on other annual types, are presented in another publication (10).

Discussion

Data presented in Table 1 for successive backcrosses to the non-bolting inbred NB1, give clear-cut genetic ratios indicating the operation of a single dominant gene for annualness. The strong linkage between the two genes, *B* for bolting and *R* for hypocotyl color, constitutes further convincing evidence regarding the assumption of a single major gene for annual growth habit. However, one should not overlook the fact that there were variations in rate of bolting not fully accounted for by environmental influences. Deliberate selection for extremely slow-bolting annuals after three generations of backcrossing produced a striking difference. By this selection an extremely slow-bolting population was produced. Genes affecting rate of bolting may be assumed, therefore, to be accessory to and possibly independent of the single major gene for annualness.

In the successive backcross generations other morphological characters appeared to be more uniform and, therefore, possibly more simply inherited than rate of bolting. In the backcross populations leaf shape and color before seedstalk initiation resembled that of the recurrent parent. The NB1 parental *rr* beets produce very light green petioles which are uniform from one plant to another. Recessive *rr* segregates in the b_3 generation were practically indistinguishable from parental NB1 beets. The

red hypocotyl *R* segregates produced uniformly pale red pigment at the base of petioles, in crown buds, and on nodes of seedstalks. The uniformity among plants was striking.

Through the use of the gene *B* for annual growth habit, the breeder may find it possible to incorporate new qualitative genes into established biennial lines more quickly than by the most rapid methods of backcrossing directly to biennials (2). The results indicate that the use of gibberellic acid to hasten reproductive development in annual beets may be very useful. By applications of gibberellic acid and proper control of greenhouse environment, including adequate light intensity, there should be no difficulty in producing four generations per year of annual beets even with relatively slow bolting annuals.

The use of annual beets for several types of indexing studies may eventually have wide applications. Indexing by use of annuals to study the influence of specific biennial pollinators in relation to cytoplasmic male sterility (5) has already been referred to. There are other important characters which may be more effectively studied by index crosses to annual beets. Bolting resistance of specific pollinators may eventually be studied most effectively in this manner after the desired isogenic annual lines are produced. Annual backcrossing to the inbred line NB1 is an effort in this direction.

Summary

Results of successive backcrosses of an annual to a bolting-resistant biennial beet are described. The biennial recurrent parent was the self-fertile inbred NB1, developed for an extreme degree of bolting resistance in fall or winter plantings in California. Annualness is attributed to a single gene derived from Munerati's annual beet, which essentially replaces the necessity for thermal induction or prolonged low temperature treatment necessary for reproductive development in biennial beets. Rate of bolting is attributed to the effect of accessory genes in association with the major gene for annual growth habit. In backcrosses to NB1, the segregates carrying the gene *B* for bolting or annual growth habit initiated seedstalks and became fully reproductive in June and July plantings under continuous illumination. Selection for extremely slow-bolting annuals after the third backcross resulted in recovery of very slow bolting annual types. These very slow-bolting beets required more time for seedstalk initiation but the final genetic ratio for annual versus biennial segregates was not affected. Applications of gibberellic acid materially hastened seedstalk initiation and reproductive development of the slow-bolting annual beets.

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The Sucrose-Sodium Relationship in Selecting Sugar Beets

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Introduction

The high negative correlation existing between sodium and sucrose content in the sugar beet has been studied and reported by several investigators. A few articles are as follows: Doxtator and Calton (1) [2] in 1950, Brown and Wood (2) in 1952, Doxtator and Bauserman (3) (4) in 1952, Wood (5) in 1954, and Finkner and Bauserman (6) in 1956. The underlying aim in the larger portion of the above endeavors has been to test the possibility of enhancement of selection for sucrose content in the sugar beet by using sodium content as a second criterion for judgment of superior individuals. Obviously, yielding ability must be simultaneously maintained or improved, lest the value of an increase in sucrose content be lost in the ultimate production of sucrose per acre. Finkner (6) concluded that use of sodium analysis as an additional aid for improvement of sucrose content of beets was of questionable value. In previous work by Great Western (5), tests of progenies of four selections having varying degrees of selection pressure by use of sodium analysis failed to provide sufficiently definitive evidence to either support or deny a value for the method.

Materials and Methods

In 1955, 1250 roots of commercial variety GW359 were taken consecutively "down the row," numbered, weighed, and analyzed for sucrose and sodium content. Roots with weight and sucrose content above the population means for those characters were classified for sucrose content. From the individuals within each sucrose classification, equal numbers of high and low sodium content roots were selected and grouped accordingly. Population means and the limits of analytical values found for the field and selected groups are to be found in Table 1.

Seed was harvested from approximately 50 roots in each group and the seed numbers assigned were C744 for the progeny of the high sucrose-low sodium selection and C745 for the progeny of the high sucrose-high sodium group. Testing of progeny was in variety trials with plots 18′ long x 6 rows wide and all rows harvested for test; 6 replications at each location.

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[1] Agronomist, Statistician, and Plant Breeder, respectively, The Great Western Sugar Company, Longmont, Colorado.

[2] Numbers in parenthesis refer to literature cited.

Table 1.—Means and Range of Analytical Values for Original Population and Selected Groups, Sucrose-Sodium Selection—1955.

Acc. or Group	Roots	Weight per Root	Range Wt. of Root	Sucrose	Range Sucrose	Na	Range Na
	(No.)	(Lbs.)	(Lbs.)	(%)	(%)	(%)	(%)
GW359	1229	3.18	8.3-0.1	15.78	20.0-9.0	.0522	.182-.010
5513 (744)	54	3.88	7.4-3.2	16.94	18.7-15.8	.022	.013-.036
5514 (745)	47	4.02	6.4-3.2	16.83	18.6-16.0	.058	.035-.122

Results and Discussion

A comparison of the performance of the two progenies and the parent for the years 1956 and 1957 is given in Table 2; test results are from three locations in each of the two years.

Table 2.—Progeny Tests of Sucrose-Sodium Selections (6 Tests).

Acc. No.	Beets per A.	Sucrose	Gross Sucrose per Acre	Sodium
	(tons)	(%)	(Lbs.)	(%)
GW359	20.23	17.04	6901	.0549
C744	19.08	17.69	6756	.0351
C745	19.91	17.43	6941	.0585
LSD 5%	0.49	0.25	193	.0052

Selection pressure appeared to be particularly effective in reducing sodium content in the low-sodium progeny; no significant change upward in sodium content in progeny of the high sodium selection is evident. A study of the means of the original population and the selected groups (Table 1) clarifies this somewhat in that the difference between the mean of the original population and that of the high sodium group is only .006; the difference between the original population mean and that of the low sodium selection is .030.

As result of both selections, sucrose content was significantly increased over the parent. Further, the high sucrose-low sodium selection resulted in progeny higher in sucrose than the high sucrose-high sodium selection, at the 5 percent level of significance. Therefore, strictly from the standpoint of increase in sucrose content, the sucrose-sodium relationship was more effective than sucrose content alone. This is contrary to the findings of Finkner (6). The significant reduction in yield of C744 as

compared to its parent, indicates that selection based upon the sucrose-sodium relationship to increase sucrose content, resulted in a loss in yield, generally associated with selections based on sucrose content alone.

It is of interest to examine the frequency distribution of the original population for sucrose and sodium content (Figure 1 and Table 3). Selections for the two groups were made in the sucrose content range of 15.70 percent to 18.70 percent as indicated in Table 1 and defined by the heavy lines of Table 3.

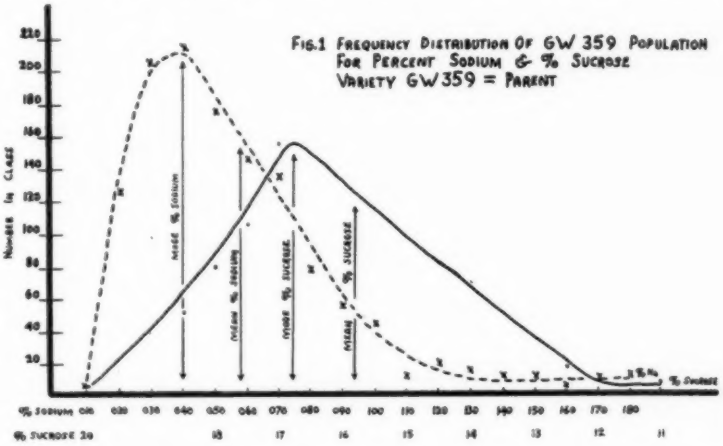

Figure 1.—Frequency distribution of GW359 population for percent sodium and percent sucrose, variety GW359 = parent.

The population distribution curve for sodium is heavily skewed to the left; for sucrose, less so but in the same direction.

It should be of perhaps more than academic interest to develop a type of beet having both high sucrose and sodium content. The data of Finkner (6) indicate a significant, positive correlation between weight of root and sodium content. Other work (7) shows a slightly less than significant, positive correlation for these characters. In Table 3 individuals having both high sucrose and sodium content would fall somewhere in the region of 0.110 plus percent on beets for sodium and 17.5 plus percent for sucrose content. In the present 1250 root population of variety GW359, no individual root meets these specifications; however, it would appear that recurrent selection methods of some type might be used to develop such a segment in a beet population.

Table 3.—Frequency Distribution of 1250 Roots of GW359 for Sucrose and Sodium Content.

% Sucrose	.010	.020	.030	.040	.050	.060	.070	.080	.090	.100	.110	.120	.130	.140	.150	.160	.170	+.170
20.5	1	1	2															
19.5		9	3	2														
19.0		22	10	4	3													
18.5		23	19	6	4													
18.0		19	29	16	9	5		2										
17.5		17	39	30	13	6	1											
17.0		23	45	40	19	12	8	5	1	1			1					
16.5		7	26	27	42	19	10	2		2								
16.0		4	19	36	21	32	19	5	3	3		1						
15.5		1	4	25	30	20	22	14	11	6		1	1					
15.0			3	13	14	22	23	15	12	2		1	2	2				
14.5			4	10	8	14	18	8	7	5					1			
14.0				2	7	11	19	11	7	7	3	2	2		1			1
13.5				1	1	2	6	6	7	3	2	3	2	4	2	1		
13.0					2	1	5	5	4	12	3	7	2	2			2	
12.5					2		2	3	1	3		2	1			1		2
12.0									1	2			1	1				
11.5								2	1								1	1
11.0											1	1		1	2	1	2	1
10.5														1	2			2
10.0													1				1	
9.5																		
9.0																		1

Percent Sodium In Beet Roots

Conclusions

1. Data are presented to show that sucrose content may be increased more by selection pressure which makes use of sodium and sucrose content than by sucrose content only.

2. Inverse relationship between percent sucrose and weight appears to be of such magnitude that marked pressure to increase sucrose content, even with use of sodium content data, is accompanied by loss in tonnage to the extent that total sucrose per acre remains relatively unchanged.

3. Conclusive evidence was obtained to show that sodium content of beets can be altered by selection methods.

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Developments in Methods for Microbiological Control in Liquid Sugar

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Representative sampling is a very important factor in obtaining an evaluation of the organism population in a lot of liquid sugar.

A grab sample taken from a storage tank may or may not be representative. A sample taken from the syrup surface of a tank car load may show an excessively high organism count, while a sample taken from the flow during unloading may show that the count is within the acceptable limits.

Continuous sampling during unloading of a tank car or storage tank appears to be the only means of obtaining a representative sample. A satisfactory device for such sampling is still to be thoroughly proven. Figure 1 shows a device for continuous sampling of liquid sugar which has been used in preliminary testing by the Spreckels Sugar Company and which may prove to be satisfactory.

The sampler is permanently attached to the syrup transfer line. The pet cock is adjusted so that the sterile sample bottle will be filled during the period of loading or of unloading. When sampling is completed the sample bottle is removed and closed with a sterile, conventional cap. The sampler is then cleaned and flame sterilized prior to the next sampling.

In attempting an organism count on a large quantity of liquid sugar, a true picture of the problem is desired. Even though continuous sampling is practiced, the chances for getting a representative organism count are better when greater amounts of sample are plated. The ABCB method, in general use by producers and consumers of liquid sugars, specifies the use of only 5 grams of dry sugar equivalent per sample. The result is multiplied by two to obtain the count on a 10 grams basis. Due to the tendency for low populations of yeasts and molds to follow the Poisson distribution (1)[2] throughout a sample of liquid sugar, it becomes quite apparent that a larger sample for plating would be desirable.

Since World War II there has been a steady increase in the use of molecular filter membranes in bacteriological analyses. These filters were originally developed some thirty-five years ago by Professor R. Zsigmondy of Goettingen, Germany. During the

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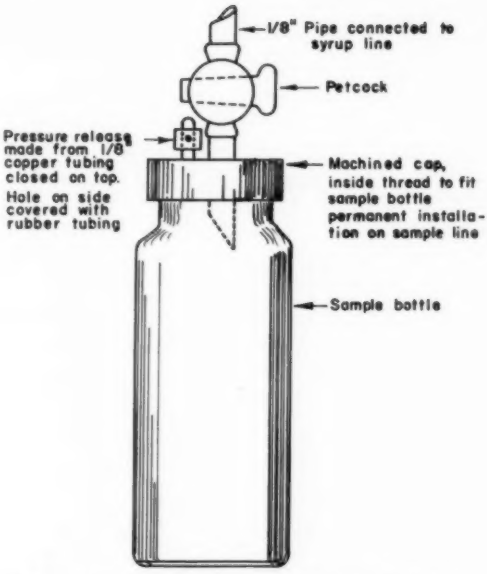
1/8" Pipe connected to syrup line
Petcock
Pressure release made from 1/8 copper tubing closed on top.
Hole on side covered with rubber tubing
Machined cap, inside thread to fit sample bottle permanent installation on sample line
Sample bottle

Figure 1.—A continuous liquid sugar sampler.

years, and particularly during the war, the manufacture of these filters reached a very high state of perfection.

When first introduced into this country the filters were principally used in water analyses but they are now being successfully applied to other bacteriological analyses and to the filtration of colloids and proteins, as well as to studies in dialysis and osmosis.

The filters are supplied in this country by at least two manufacturers and are available in several degrees of porosity. Several publications on their use have appeared (2), (3).

The type used by the Spreckels microbiological laboratory is the MF membrane (Millipore Filter Corporation) with a pore diameter of $0.45\mu \pm .02\mu$. The filters are supplied with absorbent pads for impregnation with a nutrient. The membranes with the trapped organisms are placed on these moistened pads during incubation.

One supplier (A. G. Chemical Company) furnishes "dehydrated scheduled nutrient packs," which contain MF membranes and absorbent pads with preimpregnated dehydrated nutrients. These pads need only to be moistened with sterile water prior to use.

The Spreckels microbiological laboratory has used MF membranes for more than two years in the analyses of liquid sugars, water, and air. Routine analyses of liquid sugars are still made by the ABCB method. It is hoped that the advantages of the MF method, which is more rapid than the ABCB method, will eventually be fully recognized. The MF method allows a larger sample to be used than the ABCB method, resulting in greater accuracy. The equipment for the MF method is readily portable, and ideal for field investigations which would be impractical when using other methods. The present cost per sample using prepared media pads is higher than the ABCB method. This difference, however, will eventually disappear as new nutrients are developed.

Numerous samples of liquid sugars have been analyzed by the MF method as well as by the ABCB method. The MF method has been used extensively in field investigations which have been found very beneficial for quality control.

Table 1 shows a comparison of the two methods of analyses.

Table 1.—Comparison of Fungi Counts on 10 Grams (dse) Liquid Sugar.
Samples from factory and consumer storage tanks, including others than Spreckels

Sample No.	Methods Used				Sample No.	Methods Used			
	ABCB		AG			ABCB		AG	
	Yeasts	Molds	Yeasts	Molds		Yeast	Mold	Yeast	Mold
1	74	8	57	9	18	0	2	0	0
2	4	18	2	TNTC	19	0	8	0	0
3	4	166	1	263	20	0	0	0	0
4	24	6	11	7	21	2	4	0	0
5	2	8	0	4	22	0	0	2	0
6	4	10	0	5	23	2	2	5	0
7	0	12	0	3	24	94	2	79	3
8	524	176	226	2	25	8	4	17	0
9	28	24	3	5	26	0	0	0	0
10	398	236	300	14	27	0	2	0	2
11	12	8	12	4	28	0	0	4	0
12	4	10	3	4	29	0	2	3	0
13	0	6	0	1	30	0	2	1	0
14	2510	0	1578	0	31	2	2	450	1
15	0	4	2	1	32	0	0	2	1
16	0	8	0	2	33	4	0	5	0
17	2	8	2	2	34	8	4	7	2

Summary

Conventional sampling methods now employed for microbiological control of liquid sugar are not entirely reliable due to the variation in microorganism distribution within a large volume of syrup.

Spreckels Sugar Company has conducted preliminary testing of a device which may obtain a respresentative composite sample of liquid sugar from a pipe line.

Upon obtaining a representative sample the analytical procedures for microorganism determinations must be relied upon for an evaluation of the organism population.

The accepted ABCB plating method relies on a small sugar sample. It is also slow and requires a large amount of equipment. The membrane filter method is more rapid, larger sample portions may be used, and less equipment is required.

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Toothpick Method of Inoculating Sugar Beets for Determining Pathogenicity of Rhizoctonia solani[1]

M. L. Schuster, Stanley G. Jensen, and Richard M. Sayre[2]

Received for publication March 24, 1958

Uniform infection in the field of underground parts of plants by soil-borne organisms is frequently mitigated by many factors including an apparent heterogeneous infestation of the soil by the pathogens. Thus it is difficult to predict the presence or absence of an organism such as *Rhizoctonia solani* Kuhn (*Pellicularia filamentosa* (Pat.) Rogers), an economically important crown rot causal organism of sugar beets in the irrigated fields of western Nebraska and other areas.

Attempts to provide a natural uniform soil infestation by sugar beet monoculture at the Scotts Bluff Experiment Station, Mitchell, Nebraska, did not result in an "epidemic" by the soil-borne organism but rather a variability in amount of infection of the plants in this plot from season to season (1)[3]. Greenhouse experiments to determine the crown rot potentialities of isolates of *R. solani* are affected by the comparatively slow growth of the sugar beet plant and the difficulty in obtaining crown rot symptoms by soil infestation prior to planting as a means for inoculation. Our work in 1953 and that of others (3) has shown that the induction of the seedling disease phase is not a criterion to determine crown-rot-inducing potentialities of *R. solani* isolates. This paper includes attempts to correct the difficulties in testing the sugar beet reaction to the fungus isolates and to ensure a positive inoculation of each individual root by employment of a toothpick inoculation technique.

Experimental Procedures

A modification of a toothpick method of inoculation first employed by Young (4) for ear and stalk rots of corn and by Gaskill (2) for storage-rot of sugar beets was used in these experiments. The fungus cultures were grown on two percent potato dextrose agar and quill-type, wooden toothpicks were added to the Petri dishes containing the medium. The entire preparation was accomplished about one month prior to inoculation to ensure adequate contamination of the toothpicks.

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[3] Numbers in parentheses refer to literature cited.

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At time of inoculation the sugar beets were three to four months of age. Sugar beets showing any indication of a disease were removed prior to inoculation. Each isolate was tested in duplicate with six plants per replicate and on two dates of inoculation. The toothpicks were inserted diagonally downward into the exposed basal portion of the crown of the sugar beet to a depth of approximately one and one-half inches. In the 1955 and 1956 field trials and 1953 greenhouse tests the toothpicks were forcibly inserted into the crown with the aid of pliers. In 1957 the contaminated tips of the toothpicks were inserted into holes punctured with a 6-penny nail the diameter of which was slightly less than the widest diameter of the toothpick. The insertions were made on the north side of the beets to decrease possible desiccation by the sun's rays. One toothpick per sugar beet was used and was left intact until the final disease reading.

Comparative tests were also conducted in 1957 by toothpick inoculation of the top center of the crowns, bases of leaf petioles, and by hypodermic injections of the crown with water suspensions of the fungus. Each hypodermic injection consisted of one-half milliliter of suspension made by comminuting in a Waring blender the fungus growth from two Petri dishes in one liter of sterilized distilled water. Tests performed on a slide showed that mycelial fragments of the fungus readily passed through the hypodermic needle.

The effects of four isolates on sugar beet seedlings were accomplished by incorporating the fungi in autoclaved soil. Preparatory to this the fungus growth on two percent potato dextrose agar was comminuted in a Waring blender; growth on two Petri dishes sufficed for four replications of each of four isolates. Ten segmented sugar beet seeds were sown in each pot.

The field tests were conducted at the Scotts Bluff Experiment Station, Mitchell, Nebraska. The sugar beet variety, GW304R, was used in the greenhouse tests and the field tests in 1955 and 1956. Varieties GW526 and GW359R were used in the 1953 greenhouse and 1957 field tests as test plants, respectively.

Twenty-four cultures of *R. solani* were tested for their parasitism for sugar beets. These cultures were selected from many isolates originally obtained from diseased sugar beet crowns and roots, potato stems, bean roots, pigweed roots, and one culture from plant residues in soil cropped to sugar beets the previous season.

Experimental Results

In the 1953 preliminary experiments in the greenhouse, two cultures were employed: Culture 1 and Culture 15. The former caused a high percentage of seedling kill while the latter appeared innocuous. None of the 24 sugar beet crowns of the very susceptible variety, GW526, inoculated with either of the two cultures became diseased. A six month period after inoculation of three-month old beets provided ample time for disease development and final disease readings. In this test it was assumed that conditions in the greenhouse did not favor disease development. In reality, as was shown later, the lack of pathogenicity of the isolates was involved. In fact, in the 1957 greenhouse test, Culture 1 again proved nonpathogenic to crowns of older beets, whereas cultures that induced crown or root rot in the field tests behaved similarly in greenhouse tests (Tables 1 and 2).

Table 1.—Percentage of Sugar Beets Infected by *Rhizoctonia solani* Isolates from Western Nebraska Using the Toothpick Method of Inoculation in Field Tests at the Scotts Bluff Experiment Station, Mitchell, Nebraska, 1955 to 1957.

Culture No.	Source of Culture	Plants	
		Number Inoculated	Percent Infected
0	control	288	4
1	potato stem	96	4
2	sugar beet crown	96	98
3	sugar beet crown	96	88
4	sugar beet lateral root	96	21
5	sugar beet root tip[a]	48	63
6	sugar beet root tip	48	31
7	sugar beet crown	24	75
8	sugar beet root tip	24	100
9	sugar beet crown	24	100
10	sugar beet crown	24	8
11	sugar beet crown	24	25
12	sugar beet crown	24	41
13	sugar beet crown	24	0
14	sugar beet crown	24	100
15	sugar beet crown	24	0
16	sugar beet crown	24	8
17	sugar beet lateral root	24	8
18	sugar beet crown	24	58
19	sugar beet crown	24	100
20	sugar beet root tip	24	0
21	sugar beet lateral root	24	100
22	pigweed root	24	38
23	field bean root	24	0
24	soil plant residue	24	17

[a] Refers to tip of tap root for cultures 5, 6, 8, 20.

Table 2.—Percentage of Sugar Beets Infected by *Rhizoctonia solani* Isolates Using the Toothpick Inoculation Method in Greenhouse Tests in 1957.

Culure No.[a]	Source of Culture	Plants	
		Number Inoculated	Percent Infected
0	control	10	0
1	potato stem	10	0
2	sugar beet crown	10	100
6	sugar beet root tip	10	40
7	sugar beet crown	10	100
8	sugar beet root tip	10	100
15	sugar beet crown	10	0

[a] Culture numbers correspond to those in Table 1.

Figure 1.—Sugar beet roots infected by *Rhizoctonia solani* following the toothpick method of inoculation. New toothpicks were inserted to obtain better contrast.

Although plants in many instances were beyond recovery two or three weeks subsequent to inoculation in the field tests in 1955-1957, the final disease readings awaited harvest time. Not all isolates of *R. solani* from diseased sugar beets proved pathogenic for sugar beets by the toothpick method of inoculation (Table 1). Of twenty such isolates (Cultures 2 to 21, inclusive) only nine (Cultures 2, 3, 5, 7, 8, 9, 14, 19, 21) appear definitely pathogenic (Figure 1). Four isolates (Cultures 4, 6, 11, 12) are of intermediate parasitism but possess possible virulence as in-

dicated by infection of 21, 31, 25, and 41 percent of the plants, respectively. Culture 18 may be included in the list of intermediate pathogenicity, but because of its ability to induce rotting of about 50 percent of the inoculated roots, it is possible that inadequate contamination of the toothpicks or some other undetermined variable factor may be instrumental in allaying infection. Upon repeated testing of these four cultures, a more precise cataloging of their parasitic capabilities can be made. The remainder of the sugar beet isolates (Cultures 10, 13, 15, 16, 17, 20) are ascribed to the nonpathogenic category.

A high incidence of crown rot was produced by Culture 2. Over a three-year testing period this culture induced rotting in 98 percent of the beets tested. Culture 2 can be depended upon to cause the disease by the inoculation method described. It may be considered a standard and reliable strain in determining plant reaction. In contrast, a potato isolate (Culture 1) proved consistently innocuous and thus could be considered a good comparative strain. Both of these cultures upon reisolation gave the same results as the original culture that was introduced into the plant. Culture 2, isolated in 1953, and Culture 1, isolated in 1950 retained their pathogenicity or nonpathogenicity for sugar beets for at least four and seven years, respectively. Seven additional isolates used in two to four experiments gave consistent results, making a total of nine cultures that were reliable in successive tests and displaying similar degrees of virulence.

Inoculation of the top center of the crowns and of petiole bases with Culture 2 resulted in crown rot infections in both instances. Inoculation of the crown by the use of a hypodermic needle with the virulent culture did not induce any appreciable decay indicating that desiccation of the wounded area may have been involved in lack or prevention of fungus development.

Inasmuch as *R. solani* may be pathogenic to any part of the sugar beet under natural conditions, root isolates of this organism from different areas were tested for parasitism for the crown area. Isolates from rotted crown of sugar beets did not consistently differ in capabilities to induce crown rot from those obtained from the tip of the tap roots or from lateral roots (Table 1). For example, Cultures 5, 8, and 21 were as virulent in general as isolates from diseased crowns. In other words isolates from lateral or tap roots were not necessarily restricted in their parasitism to these areas but were capable of infecting the crown as well. The cultures isolated from the three areas of the root may belong to any one of three categories: pathogenic, nonpathogenic, or of intermediate parasitism.

Table 3.—Percentage of Sugar Beet Seedlings Infected by *Rhizoctonia solani* Cultures in Greenhouse Tests in 1957.

Culture No.[a]	Percent Compared to Control		
	Pre-emergence	Post-emergence	Total
0 (control)	0	0	0
2	43	34	77
13	99	0	99
17	44	1	45
24	22	8	30

[a] Culture numbers correspond to those in Tables 1 and 2.

Studies to determine the comparative effects of cultures on seedlings and older plants indicated that cultures capable of causing seedling infection or damping-off do not necessarily induce crown rot (Table 1 and 3). Culture 13 can be destructive to seedlings but innocuous when inoculated into the crown. Culture 2 is pathogenic to seedlings and to older sugar beets. Cultures 24 and 17 are relegated to the intermediate parasitic class.

Cross inoculation tests of *R. solani* isolates from other crops grown in western Nebraska included those from potato (Culture 1), field bean (Culture 23), and pigweed (Culture 22). They did not induce crown rot, although the pigweed isolate may be pathogenic. Another isolate (Culture 24) made directly from plant residue in the soil cropped to sugar beets the year prior to isolation also did not exhibit parasitism. The number of isolates from crops other than sugar beets were too few in number to arrive at any definite conclusions with respect to their pathogenicity for sugar beets. In a preliminary manner cross inoculations of sugar beet cultures into other crops have been started and will be continued using the toothpick inoculation procedure. Culture 2 inoculated into field corn stalks under field conditions induced some decay. The testing of isolates from other crops may indicate the possible relationship of crop rotation effects and incidence of crown rot of sugar beets.

Discussion and Summary

The procedure of employing toothpicks contaminated with mycelia and sclerotia of *Rhizoctonia solani* appears promising from several standpoints in view of experimentation over a three-year period. A fairly constant amount of inoculum is brought into intimate contact with the host tissue and possible contami-

nation by secondary organisms is greatly reduced. Dessication of host and fungus is diminished because of the shape of the inserted toothpick. There is a uniformity of wounding associated with the inoculation procedure which may not be true in some other methods. By using this technique, the time of inoculation is known and the progress of the disease can be closely scrutinized. The possibilities of disease escapes are reduced. In event certain plants in a variety indicate differences in their reaction, individual roots can be reinoculated in the field or in storage to confirm the first reading. Thus, disease escapes can be found and eliminated.

Field testing was resorted to because greenhouse tests did not prove adequate owing to the poor growth of the sugar beet and slow development of symptoms. In field tests killing of plants occurred in a few weeks, whereas in the greenhouse evidence of disease did not appear for months.

Pathogenicity of the fungus isolates can be determined by obtaining crown or root infection of older roots of sugar beets. Field tests, which were mainly employed in this work, have shown that pathogenic isolates can be relied upon to retain their pathogenic qualities and produce severe rotting of the crown, root, or complete destruction of the plant. This was particularly exemplified by cultures that have been maintained for four to seven years on artificial media. Similarly, nonpathogenic cultures of *R. solani* retained this innocuous characteristic for as long a period. A group of isolates intermediate in their pathogenicity produced infection in about one-fourth to one-third of the plants inoculated. Thus reliable cultures with different parasitic capabilities have been found to retain their characteristics in successive tests.

The toothpick inoculation method appears promising in determining the reaction of varieties and species of *Beta* and of other crops that may be used in cross inoculation tests. Work of this nature is in progress in the university's greenhouse at the present time. By the toothpick method the fungus is introduced into the plant in an unnatural manner and the resulting tests may not be a true measure of the resistance for it may be too drastic a test. It may be necessary to correlate other techniques to determine the final sugar beet reaction. Regardless of the inoculation method employed it will be artificial in nature either because of the degree of wounding, number of strains used, or the amount of inoculum applied.

The toothpick method may be employed to test weed isolates onto beets and other crops and vice versa. In one field test, a

culture from sugar beets caused some necrosis of corn stalks. Information on the host range of cultures that induce crown rot of sugar beets may suggest the best crop rotations and explain the value of weed control in controlling the root diseases.

Determination of varietal reaction to *R. solani* based on the seedling stage does not truly depict the reaction of more mature beets to the serious crown rot phase that occurs most frequently late in the season. It also complicates the attempts at control of this phase through breeding by the use of seedling reaction as a criterion to judge crown rot of mature beets.

Although the test procedure possesses possibilities, the existence of strains differing in pathogenicity confounds the problem. The use of one or two isolates in determining the reaction of a variety to *R. solani* are fraught with uncertainties. Strains existant in western Nebraska differ in their virulence for sugar beets. A single isolate such as Culture 2 may or may not be relied upon to be a standard in determination of the host reaction. Although Culture 2 appeared pathogenic to three sugar beet varieties, which differ somewhat in their degree of susceptibility on the basis of field tests (1), the experiences with other disease-producing organisms and hosts should serve as a warning against such a simple solution.

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Studies on Transplanting Sugar Beets in Southern Alberta

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The maximum yield that can be attained in the production of sugar beets in northern areas depends, among other factors, upon the length of the growing season. The production of seedlings in hotbeds for subsequent transplanting into the field provides a means of extending the season.

In southern Alberta the length of season is limited by both the spring and the fall weather. Generally, the harvesting of beets commences the last week of September and continues through October. The extension of the harvesting period into November might result in some loss of crop because of bad weather and, therefore, this approach to the problem of lengthening the season is not practical.

The present practice is to seed late in April or early in May. Cold soil conditions and weather hazards limit the possibility of extending the growing season by early field planting.

The Experimental Farm, Lethbridge, Alberta, conducted a study (1)[2] of dates of seeding sugar beets over a nine-year period from 1929 to 1937. Beets were seeded at 10-day intervals from April 10 until July 1. The data for the seeding dates April 20 to June 10, inclusive, are given in Table 1. The data for the April 10 seeding have not been included as it was not possible to seed on or near that date in four out of nine years.

The data indicate no significant difference in the mean yield of beets seeded within the period from April 20 to May 10. Significant reductions in yield resulted from the seeding of beets after May 10 as compared with the April 20 seeding.

Transplanting trials were carried out with sugar beet seedlings in Quebec (3) during 1946 and 1947. Drilled beets yielded an average of 8.13 tons per acre as compared with 15.85 tons per acre from the transplanted beets. The roots from the transplanted beets were very rough and prongy and were not favored for processing.

Transplanting studies in Bavaria, reported by Rasmussen and Warley (4), resulted in yields from seedlings produced by the soil-cube method equal or superior to those obtained from drill seeding. The drilled beets were sown 21 days earlier than the soil-cube-raised plants, and the latter were established in the

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Mean Yields of Sugar Beets, in Tons per Acre, from Plots Seeded at 10-Day Intervals During the Nine-Year Period 1929 to 1937. Lethbridge, Alberta.

	Date of Seeding						
Year	April 20	May 1	May 10	May 20	June 1	June 10	Mean
1929	25.93	24.87	25.20	21.10	15.60	12.25	20.82
1930	29.97	26.82	27.90	26.01	18 01	15.96	24.11
1931	23.28	20.89	20.50	18.32	14.22	10.20	17.90
1932	15.40	14.13	17.33	16.26	10.14	13.33	14.43
1933	27.74	27.52	26.16	25.09	14.96	12.87	22.39
1934	17.54	17.54	14.42	13.12	11.40	8.31	13.72
1935	15 82	15.23	15.51	12.69	11.82	8.97	13.33
1936	17.35	13.89	15.86	14.91	12.73	9.93	14.11
1937	14.17	15.93	15.29	13.26	12.01	11.26	13.65
Mean	20.80	19.65	19.80	17.86	13.43	11.45	

L.S.D. for date means = 2.87 tons/acre at the 5% level of significance.

field more than seven weeks after they were sown. The soil-cube-raised beets frequently produced up to 2 percent higher sugar content than the drilled beets.

Rasmussen and Warley (5) also reported on the results of studies at Nottingham in which seedlings produced by the soil-cube method were subsequently transplanted into the field for comparison with drilled plots. The drilled and soil-cube plots were seeded in mid April, and the seedlings from the latter were transplanted to the open field in early June. The yield of washed beets from the soil-cube-raised plants was 14.9 tons per acre as compared with 20.0 tons per acre from the drilled beets.

Procedure

A trial was conducted at Lethbridge during 1956 on quadruplicate one-fiftieth-acre plots in a randomized block design. Ten tons per acre of manure and 700 pounds per acre of ammonium phosphate fertilizer (16-20-0) were incorporated into the seedbed. Seed was planted in flats in a greenhouse on April 3. The seedlings were transplanted to the field on May 16 at 11-inch plant intervals within the rows, and the drilled plots were sown on the same day. It was planned to transplant and seed on or before May 10, but inclement weather prevented field work between May 1 and May 16. Plot yields were determined by hand sampling on October 11 and again on October 24. An "in-place" and a "within-machine" harvester were used to harvest

the residual border rows on all plots to obtain experience in the handling of transplant beets.

The weather conditions experienced during the latter half of April and the first half of May were unfavorable to early field planting and to good plant growth. The maximum temperature recorded on May 16 was 75.5 degrees. The conditions that prevailed during the two-week interval between transplanting and the first irrigation were generally hot and dry.

One twenty-fourth-acre plots were used in the 1957 study in a randomized block design with six replications. The plot land received an application of 10 tons per acre of manure in the fall of 1956, and 300 pounds per acre of ammonium phosphate fertilizer (16-20-0) were worked into the seedbed. In addition, 100 pounds per acre of ammonium phosphate fertilizer (11-48-0) were applied in the rows with the seed and just ahead of the transplanter.

Seed was planted in flats on April 1, 1957, and the flats were placed in hotbeds which were heated by electric cables. Transplanting was carried out on May 6 at 12-inch plant intervals within the rows. One set of drilled plots was seeded in the field on April 18, and a second was sown on May 6. Harvesting was carried out by hand methods on October 2 and again on November 6.

The weather conditions experienced during the latter half of April were generally favorable to good growth subsequent to early seeding. The maximum temperature recorded on May 6 was 75.0 degrees, and relatively cool, moist weather conditions prevailed during the three-week interval between transplanting and the first irrigation.

The sugar beet seed used throughout these trials was a decorticated commercial variety supplied by Canadian Sugar Factories Ltd. Irrigation and cultivation treatments were carried out uniformly on all treatments for both years, and 22-inch row spacing was used on all plots.

The transplanter used was equipped with a water tank and injector nozzle. Water was fed into the furrow with each seedling to provide optimum conditions for plant survival.

Results and Discussion

Mean yields and percentage sucrose for the 1956 and 1957 trials are given in Tables 2 and 3. In Figure 1, the shape and size of transplanted and drill-seeded beets are compared.

The 1956 trials resulted in an average increase in yield of 9.2 tons per acre from the transplanted beets as compared with

the drill-seeded beets. The mean yield from transplanting in 1957 exceeded that from the April 18 and May 6 seeding by 4.24 and 7.51 tons per acre, respectively. The drill seedings were conducted at an earlier date in 1957 than was possible in 1956. This factor probably resulted in the smaller gain in yield attributable to transplanting in 1957 as compared with 1956.

The results for both years indicate that root growth continues throughout the normal harvest period and that yield increases can be obtained by a delayed harvest. However, weather factors make this a hazardous approach to the problem of obtaining a longer growth period.

The data in Tables 2 and 3 show that no significant differences in percentage sucrose existed between the transplanted and drill-seeded beets in both years.

Table 2.—Mean Yields of Sugar Beets and Percentage Sucrose from Drill-Seeded Beets and from Transplanted Beet Seedlings at Two Dates of Harvest. Lethbridge, Alberta, 1956.

Harvest Date	Drill-Seeded		Transplanted		Mean	
	Yield	Sucrose	Yield	Sucrose	Yield	Sucrose
	tons/ac.	%	tons/ac.	%	tons/ac.	%
October 11	15.51	16.9	26.59	17.2	21.05[1]	17.0
October 24	20.09	17.4	27.43	16.8	23.76[1]	17.1
Mean	17.80[2]	17.2	27.01[2]	17.0		

[1] Difference between harvest date means was significant at the 5% level.

[2] Difference between treatment means was significant at the 1% level.

Table 3.—Mean Yields of Sugar Beets and Percentage Sucrose from Drill-Seeded Beets and from Transplanted Beet Seedlings at Two Dates of Harvest. Lethbridge, Alberta, 1957.

Harvest Date	Drill-Seeded				Transplanted			
	April 18		May 6		May 6		Mean	
	Yield	Sucrose	Yield	Sucrose	Yield	Sucrose	Yield	Sucrose
	tons/ac.	%	tons/ac.	%	tons/ac.	%	tons/ac.	%
October 2	22.81	13.8	19.06	14.7	26.08	14.6	22.65	14.3
November 6	25.09	13.5	22.03	13.2	30.30	13.2	25.09	13.3
Mean	23.95	13.6	20.68	14.0	28.19	13.9		

L.S.D.[1] for treatment mean yields — 3.09 tons/acre

L.S.D.[1] for harvest date mean yields — 1.82 tons/acre

[1] Differences significant at the 1% level.

Figure 1.—Transplanted beets (left) compared with drill-seeded beets. Experiment Farm, Lethbridge, Alberta, 1957.

The final stand counts on the transplanted and drill-seeded beets in 1956 averaged 103 and 90 beets, respectively, per 100 feet of row. The final stand counts in 1957 on the transplanted, early-seeded, and late-seeded plots averaged 90, 90, and 112 beets, respectively, per 100 feet of row. Haddock (2) found that, with 22-inch row spacing, within-row plant intervals of 9.7 to 14.4 inches did not significantly influence yield, percentage sucrose, or percentage purity. These intervals are approximately equivalent to stands of 124 and 83 beets, respectively, per 100 feet of row. It is considered that the difference in stands encountered in the trials at Lethbridge did not influence the yields significantly.

The roots harvested from the transplant plots were not well shaped and had a tendency to pronginess, as shown in Figure 1. The mechanical harvester did a satisfactory job of topping and cleaning the root from the transplanted beets in 1956.

In Table 1 it will be noted that the April 20 seeding provided a definite yield advantage over the May 1 and May 10 seedings in the years 1930, 1931, and 1936. The May 1 and May 10 seedings yielded more than the April 20 seeding in 1932 and

1937. These data indicate the seasonal variability normal to beet production in southern Alberta. The weather conditions encountered in the spring of 1956 were in direct contrast to those experienced in 1957. It is considered that the spring seasons of 1956 and 1957 represent the extremes of conditions that can be expected in this area.

Although the seedlings wilted badly after transplanting in 1956, and to a lesser extent in 1957, recovery was rapid in both years and excellent growth was evident throughout the growing season. A difference in top growth, favoring the transplanted beets, was evident early in the season, but this difference leveled off considerably by harvest time.

The results of two years of study are in general agreement with those reported from Quebec (3), but are in disagreement with those reported by Rasmussen and Warley (4, 5). These latter studies emphasized the soil-cube culture method of producing seedlings rather than the production of seedlings under a technique that extended the season.

Conclusions

The production of sugar beet seedlings in a hotbed for subsequent transplanting to the field at normal seeding time provided increases in yield of from 4.24 to 9.2 tons per acre as compared with drill seeding. The percentage sucrose was equal in beets produced by both methods.

Sugar beet seedlings when transplanted may develop rough, slightly prongy roots.

The weather conditions encountered during the spring seasons of 1956 and 1957 represent the extremes that are experienced in southern Alberta. The increased yield obtained by transplanting can be attributed to an extension of the growing season under conditions favorable to rapid plant growth.

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Chemical Control of Annual Grasses in Sugar Beets in Montana, Wyoming, and Colorado

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Real progress has been made in chemical weed control of annual grasses during the past eight years. Chemical weed control will continue to play a major role in the realization of a complete mechanization program for sugar beet production.

Previous Tests

Chemical weed control tests in previous years in Wyoming, Montana, and Colorado have shown that DCU (Dichloral urea) at 7.3 pounds acid per acre, worked into the soil from two to four inches deep, gave promising results in controlling wild oats and grassy weeds. Dowpon, a sodium salt of Dalapon, at rates of five to eight pounds of acid per acre, applied after emergence gave satisfactory control of grassy weeds. Endothal at four pounds per acre pre-emergence, surface applied, appeared very promising with fair grass control and good broadleaf control. Indications of prolonged residual effect in the soil as a weed control was noted.

1957 Tests

The 1957 tests include the three treatments above mentioned plus EPTC (Ethel N,N-di-n-propylthiolcarbamate) at the Montana and Wyoming, locations. The Colorado tests included EPTC, Erbon (Erbon-2 (2.4,5-trichlorophenoxy) ethyl 2,2 dichloropropionate, Chloro IPC (Isopropyl-N- (3-chlorophenyl) -carbamate, and TCA (Sodium trichloroacetate).

Experimental Design and Methods

Tests were laid out in fields having a high population of grasses and broadleaf weeds. In some cases grass and broadleaf weed seeds were sown by hand during seed bed preparation or at time of planting the beets. Plot treatments followed a randomized block design with 7 to 10 replications being used.

At Sidney, Montana, and Sheridan, Wyoming, the knapsack hand sprayer was used for applying all treatments except the preplant series. At Swink, Colorado, a specially designed unit, mounted on a small tractor, was used. Preplant applications were made at Sidney with a Howry-Berg unit and at Sheridan and Swink a small roto-tiller was used to incorporate the materials into the soil.

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The tests were located on sandy loam soil at Sidney, clay loam at Sheridan, and heavy clay loam at Swink. Precipitation during the seven weeks following planting was unusually heavy for the season in areas of the test. At Sidney it amounted to 2.6 inches, Sheridan 7.8 inches, and Swink over 1 inch. Predominating grassy weeds at Sidney were *Setaria* spp.; at Sheridan *Setaria* spp. and wild oats (*Avena fatua*); at Swink *Setaria* spp. *Amaranthus retroflexus* was the most common broadleaf weed at all locations, although *Kochia* spp. was heavy at Swink.

A study of the data in the following tables seems to indicate that with good rainfall, well distributed, excellent weed control from several treatments was possible without injury to the sugar beet crop.

Harvest results for 1957 are given for the Sidney, Montana, test in Table 1. The soil in this field was a light, sandy loam type.

Table 1.—Effect of Chemical Weed Control Sprays on the Harvest Performance of Sugar Beets at Sidney, Montana, in 1957.

Treatment	Rate per Acre[1]	Tons per Acre	Percent Sugar	Gross Sugar per Acre	Percent Purity	Stand
Preplant						
DCU	7.3	12.64	19.26	4856	93.37	95
Mulch Check	.....	13.75	19.23	5275	93.75	88
Pre-Emergence						
DCU	10.0	12.43	18.53	4602	94.25	97
DCU	14.6	13.06	18.27	4756	92.44	91
Endothal	4.0	14.45	18.57	5341	92.94	88
Endothal	6.0	14.51	18.68	5401	92.31	84
EPTC	5.0	14.37	18.50	5294	92.69	93
EPTC	10.0	12.19	18.77	4532	92.64	90
DCU plus	10.0					
Endothal	4.0	13.10	18.39	4807	92.81	98
Postemergence						
Dowpon	4.0	13.45	18.99	5082	93.61	113
Dowpon	6.0	9.78	19.27	3775	93.86	86
Endothal	5.0	12.40	19.23	4755	93.69	93
EPTC	6.0	15.64	18.74	5845	93.86	98
Dowpon plus	6.0					
Endothal	4.0	10.24	19.14	3908	93.35	85
Check	.....	14.03	18.44	5174	93.40	91
LSD 5% pt.		1.97	.61	752	NS	.....

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates being used with 22 inch rows. Eight replications.

Postemergence treatments of (a) Dowpon at 6 pounds acid per acre and (b) a combination of Dowpon at 6 pounds plus Endothal at 4 pounds reduced yields significantly in both tons per acre and gross sugar per acre in the Sidney tests. Air temperatures around 85° F. at time of application probably increased their burning effect on the leaves of seedling beets. Beet roots from these two treatments as well as from Endothal at the 5-pound rate as a postemergence treatment also had significantly higher sugar content. No significant differences in purity were noted between treatments. Postemergence treatment of Endothal reduced yields of roots and gross sugar somewhat.

Table 2.—Effect of Chemical Weed Control Sprays on Harvest Performance of Sugar Beets at Sheridan, Wyoming, in 1957.

Treatment	Rate per Acre[1]	Tons per Acre	Percent Sugar	Gross Sugar per Acre	Stand
Preplant					
DCU	7.3	14.20	16.71	4744	110
Dowpon	1.0	13.76	16.63	4574	109
Endothal	4.0	14.90	16.21	4806	113
Mulch Check	.....	13.58	16.55	4489	107
Pre-Emergence					
DCU	10.0	13.78	16.80	4597	112
DCU	14.6	14.86	16.29	4830	113
Endothal	4.0	15.10	16.16	4877	111
Endothal	6.0	14.10	16.58	4664	114
EPTC	5.0	13.62	16.34	4439	111
EPTC	10.0	15.04	15.88	4773	110
DCU plus	10.0				
Endothal	4.0	14.12	16.50	4644	116
EPTC plus	5.0				
Endothal	4.0	14.85	16.29	4847	113
Postemergence					
Dowpon	4.0	14.03	16.56	4632	111
Dowpon	6.0	13.57	16.28	4414	110
Endothal	4.0	12.96	16.63	4318	106
EPTC	6.0	13.66	16.67	4542	109
Dowpon plus	6.0				
Endothal	4.0	12.51	16.27	4051	110
Dowpon plus	6.0				
Endothal and	4.0				
EPTC	5.0	13.96	16.18	4517	106
Check	.....	12.92	16.48	4225	103
LSD 5% pt.		NS	NS	NS	.....

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates being used with 22 inch rows. Eight replications.

Table 2 shows the harvest results of a similar test conducted at Sheridan, Wyoming. No significant difference for yield, percent sugar, and gross sugar per acre was noted between treatments.

The relative weed control ratings[2] as computed for the Sidney test are shown in Table 3.

Table 3.—Chemical Weed Control Ratings at Sidney, Montana. 1957.

Treatment	Rate per Acre[1]	Percent Grass Control	Percent Broadleaf Control	General Weed Control	Percent Stand[2]
Preplant					
DCU	7.3	83	48	77	95
Mulch Check	....	0	0	0	88
Pre-Emergence					
DCU	10.0	93	64	87	97
DCU	14.6	97	78	94	91
Endothal	4.0	89	68	86	88
Endothal	6.0	94	79	91	84
EPTC	5.0	98	81	95	93
EPTC	10.0	98	81	95	90
DCU plus	10.0				
Endothal	4.0	95	73	91	98
Postemergence					
Dowpon	4.0	80	47	78	113
Dowpon	6.0	81	47	77	86
Endothal	5.0	93	38	82	93
EPTC	6.0	25	30	27	98
Dowpon plus	6.0				
Endothal	4.0	94	58	89	85
Check	....	0	0	0	91
LSD 1% pt.		23	10	12	....

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates being used with 22 inch rows. Eight replications. Predominating grassy weed was pigeon grass.

[2] Number of beets in 100 feet of row.

All treatments except the EPTC postemergence gave very good grass control.

The weed control rating results of the Holly Experiment Station, Sheridan, Wyoming, test appear in Table 4. The weed control obtained at Sheridan was somewhat less than at Sidney. This may have been due to soil difference and to heavy rainfall during May and June.

At Sheridan the most effective pre-emergence treatment for grass control was a combination surface spray composed of EPTC

[3] A weed control rating system was used as calculated by Mr. Herb Day of Stauffer Chemical Company.

Table 4.—Chemical Weed Control Ratings at Sheridan, Wyoming, 1957.

Treatment	Rate per Acre[1]	Percent Grass Control	Percent Broadleaf Control	General Weed Control	Percent Stand[2]
Preplant					
DCU	7.3	54	42	50	110
Dowpon	1.0	25	16	19	109
Endothal	4.0	50	42	48	113
Mulch Check		0	0	0	107
Pre-Emergence					
DCU	10.0	59	11	42	112
DCU	14.6	60	17	44	113
Endothal	4.0	39	47	41	111
Endothal	6.0	36	51	42	114
EPTC	5.0	58	17	42	111
EPTC	10.0	60	15	42	110
DCU plus	10.0				
Endothal	4.0	64	44	57	116
EPTC plus	5.0				
Endothal	4.0	78	26	60	113
Postemergence					
Dowpon	4.0	63	12	43	111
Dowpon	6.0	72	27	56	110
Endothal	4.0	59	43	54	106
EPTC	6.0	59	6	39	109
Dowpon plus	6.0				
Endothal	4.0	77	43	65	110
Dowpon plus	6.0				
EPTC plus	5.0				
Endothal	4.0	99	69	89	106
Check		0	0	0	103
LSD 1% pt.		17	15	12	

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates being used with 22 inch rows. Eight replications. Predominating grassy weed was wild oats.

[2] Number of beets in 100 feet of row.

5 pounds and Endothal 4 pounds. The best postemergence treatment was a combination of Dowpon at 6 pounds, EPTC at 5 pounds, and Endothal at 4 pounds. In this test the Endothal and EPTC treatments alone were not as effective as at Sidney. At Sheridan, Endothal as a postemergence spray for grasses appears to be more effective than the pre-emergence treatment, whereas there is little difference at Sidney. This is probably a soil moisture effect. EPTC as a postemergence treatment shows fair grass control at Sheridan but at Sidney showed practically no control. At Swink, Colorado, EPTC at 5 and 10 pound rates applied as a pre-emergence spray gave good grass control and appears to be a very promising material.

The sugar beet germination stand as shown in Table 5 illustrates the stand reduction exhibited by the EPTC and Endothal pre-emergence treatments in Montana.

Table 5.—Influence of Chemical Weed Controls on Vigor of Beets and Grass Seedlings, Sidney, Montana, 1957.

Treatment	Rate per Acre[1]	Number of Beets in 50 Feet of Row	Sugar Beet Vigor[2]	Grass Seedling Vigor[2]
Preplant				
DCU	7.3	116	7.2	2.5
Mulch Check	.....	135	8.5	10.0
Pre-Emergence				
DCU	10.0	124	6.5	2.0
DCU	14.6	100	5.2	1.5
Endothal	4.0	81	6.8	2.2
Endothal	6.0	73	6.5	1.8
EPTC	5.0	73	5.0	1.5
EPTC	10.0	89	4.8	1.1
DCU plus	10.0			
Endothal	4.0	110	5.5	1.8
Postemergence				
Dowpon	4.0	147	5.2	3.1
Dowpon	6.0	123	3.0	3.0
Endothal	5.0	118	5.2	2.0
EPTC	6.0	149	8.0	6.6
Dowpon plus	6.0			
Endothal	4.0	92	2.8	1.5
Check	.....	142	9.0	10.0
LSD 1% pt.		32	1.1	2.8

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates being used with 22 inch rows. Eight replications. Predominating grassy weed was pigeon grass.

[2] Numerical plant vigor rating of a low of 1 to a high of 10.

The postemergence treatments of Dowpon at 6 pounds and the combination treatment of Dowpon at 6 pounds plus Endothal at 4 pounds reduced the sugar beet plant vigor considerably. DCU at 7.3 pounds preplant and EPTC at 6 pounds postemergence retarded the beets the least of any treatments.

Comparing the sugar beet vigor and the grass seedling vigor of Table 5 from Sidney, Montana, with Table 6 from Sheridan, Wyoming, reveals that similar treatments showed more effective weed control and also more setback to the beets at Sidney than at Sheridan.

In general, more effective grass control was obtained under the drier conditions at Sidney than under exceptionally good moisture conditions at Sheridan.

Erbon at all rates drastically reduced the stand of beets at Swink, Colorado, indicating that the rates used were probably too high. EPTC, both liquid and granular, was very promising.

Table 6.—Influence of Chemical Weed Controls on Vigor of Beets and Grass Seedlings, Sheridan, Wyoming, 1957.

Treatment	Rate per Acre[1]	Number of Beets in 100 Inches	Sugar Beet Vigor[2]	Grass Seedling Vigor[2]
Preplant				
DCU	7.3	73	8.1	6.0
Dowpon	1.0	74	9.9	8.1
Endothal	4.0	71	8.2	4.1
Mulch Check	——	75	10.0	10.0
Pre-Emergence				
DCU	10.0	71	10.0	5.9
DCU	14.6	70	9.9	9.2
Endothal	4.0	71	9.4	7.6
Endothal	6.0	70	9.2	8.0
EPTC	5.0	70	9.9	8.1
EPTC	10.0	71	10.0	8.1
DCU plus	10.0			
Endothal	4.0	67	8.8	7.5
DCU plus	10.0			
Endothal plus	4.0			
EPTC	5.0	69	8.9	4.0
Postemergence				
Dowpon	4.0	74	9.0	5.2
Dowpon	6.0	64	8.1	2.8
Endothal	4.0	62	7.6	7.5
EPTC	6.0	66	10.0	7.6
Dowpon plus	6.0			
Endothal	4.0	52	6.5	2.4
Dowpon plus	6.0			
Endothal plus	4.0			
EPTC	5.0	42	4.1	0
Check	——	78	10.0	10.0
LSD 1% pt.		13	.8	1.2

[1] Pounds of acid equivalent on a broadcast basis. All applications were made in 6 inch bands, with approximately one-fourth of the above rates used with 22 inch rows. Eight replications. Predominating grassy weed was wild oats.

[2] Numerical plant vigor rating with a low of 1 to a high of 10.

Table 7.—Beet Count, Weed Counts, and Vigor of Beets, Miscellaneous Herbicides, Swink, Colorado, 1957.

Treatments[1]	No. Beets per 72" Row	No. Grassy[2] Weeds	No. Broadleaved Weeds	Vigor of Beets[3]
Check	31.8	14.1	10.7	1.2
Erbon 6	11.8	3.7	3.8	4.2
Erbon 9	4.3	2.5	1.5	5.0
Erbon 12	3.9	2.7	1.2	5.0
EPTC 5 L	29.6	8.1	6.7	1.6
EPTC 10 L	26.0	1.0	2.6	2.4
EPTC 5 G	34.0	1.8	2.3	2.5
EPTC 7.5 G	18.9	0.7	1.8	3.5
CIPC 4	21.6	7.1	3.0	3.0
CIPC 6	16.7	2.4	3.5	3.6
LSD 5% pt.	6.82	7.48	3.06	0.61
LSD 1% pt.	9.06	9.93	4.06	0.81

[1] L = Liquid; G = Granular.

[2] Per 3 square feet — 6" wide by 72" long.

[3] June 18, 1957; 1 = Most vigorous on scale of 1 to 5.

Table 8.—Thinning and Harvest Data, Miscellaneous Herbicides, Swink, Colorado, 1957.

Treatment	Stand[1]	Percent Sucrose	Tons per Acre	Gross Sugar Lbs./Acre
Check	115.7	12.58	22.52	5695
Erbon 6	50.0	11.92	15.43	3713
Erbon 9	26.5	11.22	8 62	1962
Erbon 12	15.1	10.72	4.51	942
EPTC 5 L	112.8	13.04	22.48	5856
EPTC 10 L	116.3	12.72	23.36	5948
EPTC 5 G	121.5	12.49	22.90	5721
EPTC 7.5 G	105.8	12.11	22.46	5428
CIPC 4	94.1	12.67	21.55	5461
CIPC 6	77.7	12.37	20.15	4970
LSD 5% = pt.	11.70	0.52	2.166	563
LSD 1% = pt.	15.54	0.69	2.877	747

[1] Beets per 100 feet of row.

Summary

1. In the tests reported more effective grass control was obtained under the drier moisture conditions of the sandy loam soil at Sidney, Montana, than on the heavier soil at Sheridan

with an excessively high rainfall. This is somewhat contrary to general experience. Possibly loss of the chemicals by leaching can partially explain this for Sheridan.

2. Preplant treatments of DCU at 7.3 pounds per acre and Endothal at 4 pounds per acre, both gave satisfactory control of grassy weeds without reducing beet yields.

3. The following pre-emergence treatments gave satisfactory control of grassy weeds without reducing beet yields: (a) Endothal at 4 to 6 pounds per acre; (b) EPTC at 5 pounds per acre.

(4) Postemergence treatments exhibiting satisfactory grassy weed control at both locations were Dowpon at 4 to 6 pounds per acre and Endothal at 5 pounds per acre at Sheridan.

5. Air temperatures near 85° F. caused the postemergence treatments of Dowpon and Endothal to severely burn the sugar beets in the Montana tests.

6. Percent purity was not affected by any treatment.

7. The germination stand of beets was reduced in Montana by the pre-emergence treatments: (a) Endothal at 4 to 6 pounds per acre and (b) EPTC at 5 to 10 pounds per acre, but such was not the case in Wyoming. The Erbon treatments drastically reduced germination stands of beets at Swink, probably because the rates of application were so heavy.

8. In Wyoming the stand was significantly reduced by the following postemergence treatments: (a) Dowpon at 6 pounds, (b) Endothal at 4 pounds, and (c) the combinations of these treatments.

9. Endothal has given somewhat more effective grassy weed control in Montana than in Wyoming when applied pre-emergence, which may be due to kind of weed present.

10. A 5 pound per acre or lower rate of EPTC applied pre-emergence seems to be indicated for Sidney but heavier rates can be used in the Sheridan and Swink areas.

11. Postemergence applications of Dowpon at 6 pounds per acre was a very effective grassy weed control at Sidney. Sugar beet plants were slightly burned and yields reduced by this treatment in the Sidney tests but such was not the case at Sheridan.

12. The reasons for the great variation in effectiveness of grass control between locations by certain of these chemical treatments is not fully known. The factors of climatic variation (temperature and moisture relations), soil type and difference in nature of the predominating grassy weeds undoubtedly played an important role.

The Effect of Different Levels of Fertility on the Chemical Composition of Sugar Beets

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The composition of sugar beets was reported by Dunn and Rost (4)[2] to vary according to the conditions under which the beets were grown. Various fertility practices were shown by Hill (5) to produce large differences in the yield of sugar beets on long-term rotation experiments at Lethbridge, Alberta. This paper reports the results of a study that was undertaken to assess the effect of soil fertility on the composition of sugar beets grown in two rotations at the Experimental Farm, Lethbridge.

The two rotations involved in this experiment were set out in 1929 with duplicate plots selected at random (i.e., for the 8-year rotation 16 plots were required) (5) on an old alfalfa field which showed signs of phosphorus deficiency. One was an 8-year rotation consisting of wheat seeded down to alfalfa, 3 years of alfalfa, wheat, 2 years of sugar beets, and wheat. In this rotation four management practices resulting in four levels of fertility were followed:

1. 30 tons of barnyard manure applied to the wheat stubble and plowed under in the fall preceding the first year of sugar beets.
2. 100 pounds of fertilizer (0-43-0 until 1948 and 11-48-0 since 1948) at the time of seeding with each of the two sugar beet crops.
3. Manure and fertilizer applied and handled as in 1 and 2.
4. No additions.

The other was a 4-year rotation consisting of wheat seeded down to sweet clover, clover hay, and 2 years of sugar beets. In this rotation six management practices were followed:

1. 20 tons of barnyard manure applied to the sweet clover stubble and plowed under in the fall preceding the first year of sugar beets. (Two crops of sweet clover hay were removed.)
2. 100 pounds of fertilizer (0-43-0 until 1948 and 11-48-0 since 1948) applied at seeding time with each of the two sugar beet crops.
3. Manure and fertilizer applied and handled as in 1 and 2.
4. No additions.

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[2] Numbers in parentheses refer to literature cited.

Table 1.—The Effect of Management Practices on the 1956 and Long Term (1929-1956) Average Yield, Sucrose Content, and Apparent Purity of Sugar Beets Grown in an Eight-Year Rotation at Lethbridge, Alberta.

Treatment[1]	Root Yield		Sucrose Content		Purity	
	1956	Av.	1956	Av.	1956	Av.
	Tons/Ac.	Tons/Ac.	%	%	%	%
First-Year Beets						
Manure and fertilizer	14.59	20.53	16.0	15.6	87.4	85.0
Manure	11.92	19.39	16.2	15.8	88.0	85.4
Fertilizer	11.44	13.53	15.2	15.7	87.4	85.4
No additions	2.22	4.94	16.7	15.3	86.0	84.2
Second-Year Beets						
Manure and fertilizer	15.85	19.84	15.4	16.2	88.1	85.8
Manure	15.59	18.35	14.2	16.3	86.6	85.7
Fertilizer	11.80	15.19	14.9	15.8	88.2	85.4
No additions	5.50	6.20	15.2	15.6	88.4	84.6

[1] 30 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Table 2.—The Effect of Management Practices on the 1956 and Long Term (1929-1956) Average Yield, Sucrose Content, and Apparent Purity of Sugar Beets Grown in a Four-Year Rotation at Lethbridge, Alberta.

Treatment[1]	Root Yield		Sucrose Content		Purity	
	1956	Av.	1956	Av.	1956	Av.
	Tons/Ac.	Tons/Ac.	%	%	%	%
First-Year Beets						
Manure and fertilizer	16.34	20.98	16.6	16.7	88.3	86.0
Manure	13.51	19.87	16.5	16.7	87.4	86.3
Fertilizer	14.85	16.01	16.9	16.5	87.1	85.7
No additions	6.02	8.59	15.4	16.2	89.0	85.6
Green manure and fertilizer	14.00	16.34	16.6	16.5	88.8	86.3
Green manure	4.64	8.84	15.9	16.2	86.4	85.6
Second-Year Beets						
Manure and fertilizer	17.38	19.58	16.3	17.1	88.1	86.4
Manure	14.78	17.67	15.4	16.8	87.0	86.6
Fertilizer	16.92	16.00	14.9	16.5	87.2	86.0
No additions	9.36	8.60	16.1	16.1	87.0	85.4
Green manure and fertilizer	15.56	16.37	16.2	16.7	87.1	86.2
Green manure	9.54	8.36	13.7	16.0	85.1	85.0

[1] 20 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

5. Second crop of sweet clover plowed under as a green manure and fertilizer as applied in 2.
6. Second crop of sweet clover plowed under as green manure.

Samples from all the sugar beet plots were taken from both rotations in 1956 at the time of harvest. The roots were cut into small cubes and dried at 180° F. to determine the moisture content. The dried samples were then ground and kept in glass containers for analysis. The following methods were used for determining the various constituents: Ash by ignition and total nitrogen by Kjeldahl method (1), phosphorus by molybdate method (7), magnesium by versenate method (2), calcium, sodium, and potassium by means of the flame photometer (6).

Results

The 1956 and long-term average yields, sucrose percentages, and apparent purity for both sugar beet crops in the 8-year rotation are shown in Table 1. Comparable data for the 4-year rotation appear in Table 2. The yield of dry matter and the chemical content of sugar beet roots produced in 1956 are shown in Table 3 for the 8-year rotation and in Table 4 for the 4-year rotation.

Table 3.—The Effect of Management Practices on the Mineral Content of Sugar Beet Roots Grown in an Eight-Year Rotation at Lethbridge, Alberta, 1956.

Treatment[1]	Dry Matter	Ash	N	P	K	Na	Mg	Ca
	Lb./Ac.	%	%	%	%	%	%	%
First-Year Beets								
Manure and fertilizer	6,157	2.71	0.92	0.094	1.128	0.205	0.287	0.092
Manure	5,030	3.32	1.04	0.068	1.410	0.310	0.304	0.116
Fertilizer	4,828	2.98	0.98	0.086	1.190	0.315	0.271	0.102
No additions	937	3.60	1.28	0.076	1.580	0.185	0.252	0.137
Average	4,238	3.15	1.06	0.081	1.327	0.254	0.278	0.112
Second-Year Beets								
Manure and fertilizer	6,689	3.62	1.06	0.121	1.345	0.475	0.305	0.103
Manure	6,579	3.83	1.12	0.097	1.465	0.510	0.392	0.114
Fertilizer	4,980	3.66	1.12	0.086	1.470	0.315	0.308	0.134
No additions	2,321	3.44	1.06	0.064	1.628	0.255	0.306	0.132
Average	5,142	3.64	1.09	0.092	1.477	0.389	0.328	0.121

[1] 30 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Table 4.—The Effect of Management Practices on the Mineral Content of Sugar Beet Roots Grown in a Four-Year Rotation at Lethbridge, Alberta, 1956.

Treatment[1]	Dry Matter	Ash	N	P	K	Na	Mg	Ca
	Lb./Ac.	%	%	%	%	%	%	%
First-Year Beets								
Manure and fertilizer	6,895	2.22	0.70	0.161	1.020	0.065	0.139	0.102
Manure	5,701	2.73	0.64	0.169	1.265	0.130	0.142	0.087
Fertilizer	6,267	2.20	0.66	0.114	0.823	0.068	0.150	0.123
No additions	2,540	2.97	0.80	0.092	1.333	0.140	0.270	0.114
Green manure and fertilizer	5,908	2.58	0.78	0.126	1.130	0.105	0.225	0.107
Green manure	1,958	2.92	0.85	0.081	1.198	0.195	0.291	0.125
Average	4,878	2.60	0.74	0.124	1.128	0.117	0.203	0.110
Second-Year Beets								
Manure and fertilizer	7,334	2.92	0.75	0.172	1.265	0.280	0.191	0.090
Manure	6,237	3.69	1.00	0.142	1.505	0.513	0.230	0.075
Fertilizer	7,141	2.77	0.72	0.138	1.103	0.210	0.274	0.091
No additions	3,950	3.09	0.84	0.096	1.205	0.258	0.245	0.099
Green manure and fertilizer	6,566	3.05	0.88	0.124	1.115	0.310	0.243	0.109
Green manure	4,026	3.52	1.00	0.099	1.315	0.415	0.184	0.114
Average	5,876	3.17	0.86	0.128	1.251	0.331	0.228	0.096

[1] 20 tons manure plowed under in the fall preceding sugar beets and 100 pounds 11-48-0 applied at time of seeding sugar beets for each of the two crop years.

Discussion

The striking differences in yield as shown in Tables 1 and 2 definitely point out the value of manure and phosphatic fertilizer in sugar beet culture for southern Alberta. The sugar content and apparent purity of the beets were not influenced by fertility level to the same extent as was the yield.

As would be reasonable to expect, the dry matter content closely paralleled the yield trends. There was no definite trend in either the ash or nitrogen content of the beets, although the application of phosphorus to the first-year beets seemed to result in a lower nitrogen content of the beet roots. Apparently, the decomposition of the manure and green manure during the first year of sugar beet production resulted in more nitrogen being available for the second-year beets, so that the nitrogen content was higher in the roots of the second-year beet crop than in those of the first-year crop. The effect of phosphorus fertilizer on nitrogen content was not as apparent in the second-year beets.

Phosphorus seemed to be the most limiting element in these experiments, so the effect of phosphorus on the composition of

the roots was very pronounced. An indication of the effect of the barnyard manure on phosphorus availability may be seen when the two rotations are compared. The 4-year rotation received 20 tons of manure every 4 years, and beets from this rotation contained more phosphorus than those from the 8-year rotation, which received 30 tons of manure every 8 years. The effect of the decomposing barnyard manure on phosphorus availability also is shown. In both rotations the sugar beets that received neither manure nor fertilizer had the lowest phosphorus content. Under the conditions of this experiment, the practice of plowing under green manure was of little value. This was probably due to the small amount of organic matter produced by the second crop of sweet clover.

Potassium has not been a limiting factor in the production of sugar beets in southern Alberta (3). The addition of phosphorus resulted in lower potassium content of the beets in every case but one, which could be a reflection of the differences in yield. The check plots, receiving no manure or fertilizer, produced low-yielding roots with a high potassium content.

No general patterns due to management practices were apparent in the sodium, magnesium, and calcium content of the sugar beet roots.

In no case were the differences in the amounts of the constituents of the sugar beet roots very great. There were greater differences in the amounts of these constituents as a result of rotation practices than there were because of management practices within the rotation. Management practices within rotations seemed to have a greater effect on yield than they had on the composition of the sugar beet roots at harvest. Differences in chemical composition may have important effects on the quality of the sugar beet roots, although sugar content and apparent purity within rotations in this experiment did not appear to be affected by the chemical composition.

Summary

The addition of phosphorus fertilizer, barnyard manure, and fertilizer and manure to phosphorus-deficient long-term rotation experiments resulted in large increases in the yield of sugar beet roots grown in the rotations.

The addition of phosphorus fertilizer resulted in higher phosphorus and lower potassium contents of the beet roots, and seemed to lower the nitrogen content of the first-year roots.

The addition of barnyard manure resulted in increased phosphorus availability in the soil as indicated by higher phosphorus content of beet roots grown on plots receiving manure.

Chemical analysis of the sugar beet roots showed only small variations in the composition of the roots.

Management practices within rotations seemed to have a greater effect on yield than they had on the composition of the sugar beet roots at harvest.

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Relationship Between White Pan pH and Saponin Content of the Sugar

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In previous work on saponin content of refined sugar and its relation to floc production in beverages, (1)[2], (2), it was found that sugar containing less than 2 p.p.m. saponin would very likely not produce floc in susceptible carbonated beverages. It was also determined that at some factories all the sugar produced contained less than 2 p.p.m. saponin. At others all the production analyzed 6 p.p.m. or more of saponin. At still other factories the saponin content in the granulated sugar varied rather widely.

While attempting to correlate saponin concentrations in various factory syrups with concentrations observed in granulated sugar, the campaign composite white massecuites from the seven operating factories were autoclaved to effect solution of the grain, diluted to 66.5 Brix and stored in the refrigerator. The next day it was noted that a scum had formed on the solution from Factory B (high saponin sugar producer). This scum was found to be 65 percent saponin. This massecuite composite had an unusually low pH value of 6.5, which led to the hypothesis that perhaps the soluble saponin originally present in the standard liquor had been precipitated by pH drop in the white pan. As the first step in checking this hypothesis, saponin was determined on all seven white massecuites without previous filtration. As may be noted in Table 1, the range was from 52 to 107 p.p.m. on solids with a pH range from 6.5 to 8.8. There was no correlation whatever between saponin content of these campaign composite

Table 1.—pH and Saponin Content of Unfiltered White Massecuite Composites.

Factory	Massecuite pH	Saponin p.p.m. on D.S.
R	8.5	52
S	7.7	70
C	8.0	71
B	6.5	75
U	7.2	79
T	8.5	83
A	8.8	107

[1] General Chemist, Utah-Idaho Sugar Company, Salt Lake City, Utah, and Chief Chemist, General Laboratory, Utah-Idaho Sugar Co., Midvale, Utah, respectively.

[2] Numbers in parentheses refer to literature cited.

white massecuites and the saponin content of the corresponding sugar. As a matter of fact, the 107 p.p.m. massecuite was from Factory A, a very low saponin sugar producer.

If the foregoing hypothesis is correct, the saponin concentration in the filtrate of filtered low pH massecuite should be much lower than on the same massecuite unfiltered. This was exactly the case as shown in Table 2.

Table 2.—pH and Saponin Content of Unfiltered and Filtered Massecuite Composites.

Factory	Massecuite	pH	Saponin p.p.m. on D.S.	
			Unfiltered	Filtered
A	White	8.8	107	101
B	White	6.5	75	10
A	Low Raw	9.4	560	455
B	Low Raw	6.0	470	75

Note that in high pH massecuites, approximately the same concentration of saponin was obtained from both filtered and unfiltered solutions. On the other hand, about 85 percent of the saponin contained in low pH massecuite was retained on the filter.

Aliquots of the low pH massecuite from Factory B were treated with NaOH solution to raise the pH to 7.6 and 8.3 respectively. The treated aliquots were stirred for 10 minutes, filtered and saponin determined on the filtrate. Similarly, portions of the high pH massecuite from Factory A were brought to pH 6.6 and 5.9 with HCl, filtered, and the filtrate examined for saponin. Results are shown in Table 3. Progressive increase in pH puts progressively more saponin in solution. A progressive decrease in pH progressively precipitates the saponin in the massecuite.

Table 3.—pH and Saponin on Massecuites Treated With NaOH and HCl.

Factory	pH	Saponin in Filtrate p.p.m. on D.S.
B	6.5	10
	7.6	21
	8.3	33
A	8.8	107
	7.2	94
	5.9	73

It had been demonstrated many times (2), both in the factory on the white centrifugals and in the laboratory on the laboratory centrifugal that no amount of wash water would effect a decrease of more than 1 or 2 p.p.m. saponin in the sugar. It had also been established that recrystallizing a refined granulated sugar of high saponin content by re-boiling in the laboratory vacuum pan did not significantly lower the saponin content of the resultant sugar. However, at the time this work was done, no adjustment in pH was made on the syrup feeding the vacuum pan. To determine the effect of higher pH during recrystallizing, the following experiment was set up. Refined granulated sugar containing 16.2 p.p.m. saponin was dissolved in distilled water to a 65 Brix syrup. A pan was boiled without any pH adjustment. A second pan was boiled from an aliquot of the syrup adjusted to pH 7.9 with sodium hydroxide and a third from an aliquot of the syrup adjusted to pH 9.0. Each pan was grained, boiled on an intermittent feed to a normal grain size, Brixed to about 92.0, spun in the laboratory centrifugal, and washed with boiling distilled water in an amount equivalent to 20 quarts per factory sized machine. The resultant sugar was then analyzed for saponin. Results are shown in Table 4.

Table 4.—Saponin on Sugar Re-boiled at Various pHs.

Pan No.	pH	Saponin p.p.m.
1	7.1	14
2	7.9	5
3	9.0	2

As a result of these laboratory findings a careful study was made of the pH history throughout the process of each of the seven factories and some rather significant facts were noted.

1. Factories (A) having sugar production consistently low in saponin were those in which the pH remained constant at a value of not less than pH 8.5 from thin juice to molasses, or were factories in which there was a rise in pH through the process from thin juice to molasses, provided the pH of the white pan was not below 8.5.

2. Factories (B) producing sugar consistently high in saponin were those which had a drop in pH from thin juice to molasses resulting in a white pan pH below 8.5; usually considerably below.

3. Factories (C) in which saponin in the sugar was variable were those in which the pH carried through the process at a constant figure but this pH was lower than 8.5.

Typical examples of each of these are shown in Table 5.

Table 5.—Average pH Values on Process Juices at Three Factories.

Station	pH		
	Factory A	Factory B	Factory C
Second Carbonation	9.0	9.2	9.3
Thin Juice	8.2	8.6	8.1
Thick Juice	8.8	7.4	8.0
Standard Liquor	8.7	7.4	8.0
White Pan	8.8	7.0	8.0
High Raw Pan	9.0	6.6	7.8
Low Raw Pan	9.1	6.4	7.8

The next step obviously was to apply this information to full scale production. In the case of type "C" factories, this turned out to be relatively easy. The pH of thin juice was maintained high enough so that the white pan was boiled at pH 8.6 or higher. To do this and still get some sulfur dioxide in the juice it was necessary to raise second carbonation pH considerably higher than had been carried in the past, higher in some cases than the optimal second carbonation alkalinity. Table 6 shows typical pH values under this system.

Table 6.—Typical pH Values Operating in the Higher pH Range.

Station	pH
Second Carb.	9.7
Thin Juice	9.1
Thick Juice	8.8
Standard Liquor	8.7
White Pan	8.7
High Raw Pan	8.6
Low Raw Pan	8.6

Operating in this manner resulted in practically one-hundred percent of the sugar analyzing less than 2 p.p.m. saponin.

The problem of producing low saponin sugar at Factory B was not so simple. Here the juice contains a high concentration of nitrogen compounds. These continuously break down through

the five evaporators and through all three pans with the evolution of ammonia liberating the corresponding organic acids into the juice, resulting in a progressive drop in pH through the evaporators and through the sugar end. No combination of lime addition nor of alkalinities in first and second carbonation was found to have much effect on this decomposition. Even with second carbonation pH raised to 9.8 and thin juice to 9.4 the white massecuite was still no higher than pH 8.0 and saponin concentration in the sugar was as high as 10 p.p.m.

The only way to get the white pan pH up to the required 8.6 was to add caustic soda. It was added into the charge line of the pan as the 25 percent solution. Sufficient was added with the graining charge to bring it to pH 8.8 to 9.0. To maintain this pH it was necessary to add caustic at intervals until the pan was ready for Brixing. A pH meter was set up on the pan floor and the massecuite checked about every 15 minutes. This was necessary because if the pH at any time during the boiling cycle dropped more than about 0.3 pH the sugar would be above 2 p.p.m. saponin. Conversely, if the pH became too high (9.4) considerable color developed. A typical boiling cycle is shown in Table 7. By using this procedure it was possible to consistently produce sugar in the range 0.5 to 1.5 p.p.m. saponin.

Table 7.—Typical Boiling Cycle on White Pan With Caustic Soda Addition.

Graining charge 700 cu. ft. pH 8.1	
41.2 lbs. caustic added—pH 9.0	
At 800 ft., pH 8.7—15.5 lbs. caustic added, pH 9.0	
1000 ft., pH 8.7—10.3 lbs. caustic added, pH 8.9	
1200 ft., pH 8.7—10.3 lbs. caustic added, pH 8.8	
1400 ft., pH 8.7—10.3 lbs. caustic added, pH 8.8	
1500 ft., pH 8.6—10.3 lbs. caustic added, pH 8.8	
1600 ft., pH 8.6—10.3 lbs. caustic added, pH 8.9	
Total caustic added 108.2 pounds	
1650 cu. ft. massecuite pH 8.8	

It is obvious that this is not an ideal solution to the problem of floc-producing substances in refined beet sugar. The technique is difficult to control, is expensive and was used only for the sugar to be allocated to the beverage industry. Even with good control there is a continued color build-up in the syrups and purities tend to get somewhat out of hand. For this reason the system is operated intermittently, allowing time for the sugar end to clear out between cycles. However, in spite of the mani-

fest disadvantages of high operating pH values and caustic addition to white pans where necessary, such technique has solved a very perplexing problem for us. Certainly there must be some better method of eliminating the few parts per million of these offending non-sugars. Further developments by the industry's technologists are awaited with interest.

Summary

Evidence is presented that the concentration of saponin in refined granulated beet sugar may be influenced by pH conditions in the white pan during the boiling cycle. Methods of controlling this pH under two sets of conditions are presented.

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The Incidence of Heterodera Schachtii Soil Population Densities in Various Soil Types

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Introduction

Many observations on the relationship between the sugar beet nematode, *Heterodera schachtii* Schmidt, 1871, and soil type lend support to the view that more serious nematode damage occurs in lighter soils. This would naturally lead to the conclusion that some characteristic or a complex of factors favoring *H. schachtii* development are inherent in light soils. However, heavy soils can and do allow the development of high population densities of *H. schachtii* (3, 7)[2].

Wallace (7) suggests that soil structure rather than soil texture is a more acute criterion in the study of *H. schachtii* response to soils and soil phenomena. Soil structures that favor plant growth also favor *H. schachtii* soil population development (1, 6, 7). Soil population is defined here as the infective larval force present in the soil, not the potential which would include the unhatched eggs within cysts. Recent studies (6, 7, 8) illustrate the complex interrelationships of soil structure, temperature, moisture content, aeration, and possibly other unknown factors on the emergence and movement of *H. schachtii* larvae.

The Beet Sugar Development Foundation initiated a study of the incidence of nematodes in sugar beet production.[3] One factor investigated was the correlation between nematode population densities and soil type.

Procedure

California, Colorado, and Michigan represent the leading states in sugar beet acreage as the far western, central, and general eastern limits of the sugar beet growing regions, respectively. Distribution and allocation of samples were based on sugar beet acreage planted with the sampling of approximately one field representative of 1600 acres. Sampling was timed to collect in the selected areas approximately at midseason.

The collection of samples was allocated to company fieldmen who are familiar with their particular territories and the sugar beet fields therein. Fields with a known or suspected nematode

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[1] Nematologist, Beet Sugar Development Foundation, Fort Collins, Colorado.

[2] Numbers in parentheses refer to literature cited.

[3] The assistance and cooperation of the officials of Agricultural Research Service of the United States Department of Agriculture and the officials and personnel of the beet sugar industry which helped make this study possible is gratefully acknowledged.

infestation were selected and samples were taken from each field. Fields selected for sampling were of a representative soil type used for growing sugar beets in the fieldman's particular area. Fields where nematode control practices by soil fumigation had been employed were avoided.

Four samples were taken from each field. Sample A was taken from the apparent center of an infested area as observed by sugar beet growth. Sample B was taken midway from the apparent center to the apparent edge of the infested area. Sample C was collected at a point believed to be the edge of the infested area. The collection of Sample D was from a presumably unaffected area of the field. If a field contained more than one infested area, only one such infestation was sampled.

The method of sampling was as follows: Each sample consisted of one whole sugar beet, top included, and one quart of soil. Sugar beet roots were dug, rather than pulled, to preserve the maximum number of secondary roots. Soil surrounding the beet one foot square and to the depth of the actively growing fibrous roots or ten inches, whichever was greater, was thoroughly mixed on a clean surface for each sample. Newspapers were most often used. A one-quart aliquot of soil was then taken. The beet and the quart of soil were placed in a plastic bag with proper identification. The four samples from each field were then placed in a tare bag for transportation to the collection and processing center for that particular area.

The nematodes were separated from the soil using the gravity-screening technique (2) and preserved in five-dram vials in five percent formaldehyde, after being relaxed by heat.

Samples of the beet were taken from the fibrous roots, the tap root, the crown, the petioles, and the leaf blade. The beet samples were then preserved and stained in steaming acid fuchin in lacto-phenol (4, 5). A total of 1,041 soil samples and 1,031 aggregate beet samples were examined at the nematode laboratory of the Beet Sugar Development Foundation in Fort Collins, Colorado.

Estimates of nematode populations were based on a proportionate number of the total nematodes in each soil sample as obtained by the dilution method. Root population estimates of nematodes were made by direct observation.

Results and Discussion

Ten general soil types were encountered in the three states. The soil types, frequency of appearance, and frequency of *H. schachtii* infestation, respectively, are as follows: (1) loam 27, 22; (2) fine sandy loam 24, 12; (3) sandy loam 85, 57; (4) silt

loam 9, 7; (5) sediment loam 3, 3; (6) clay loam 97, 85; (7) silty clay loam 17, 9; (8) sandy clay loam 6, 6; (9) muck 2, 2; (10) peat 3, 3.

High nematode population densities, 101 or more *H. schachtii* larvae per quart of soil, occurred in all soil types (Figure 1). *H. schachtii* population density estimates of 1 through 100 larvae per quart of soil were assigned to 19, or 9.19 percent, of the fields found infested. Nonclay soils accounted for 11 and clay soil for 8 of these low population density fields. These data are weighted as compared with fields of higher population densities because fields with visible growth symptoms were sought out for sampling. This procedure would naturally cause population density ratings to be grouped at the higher levels.

Loam, sandy loam, and clay loam soils were encountered most frequently, comprising 82.12 percent of the sugar beet fields sampled. Wallace (7) found the emergence of larvae from 100 cysts decreased from about 3,000 larvae to about 1,000, 100, and 50 or less larvae in seven days as the clay content was increased from none, to one, five, and 18 percent, respectively, in structureless mixtures of sand and clay. Of the 86 clay loam soil samples, 79, or 91.86 percent, allowed the development of a dense soil population of *H. schachtii* larvae (101 or more larvae per quart of soil) (Figure 1). These results suggest that a dense soil tex-

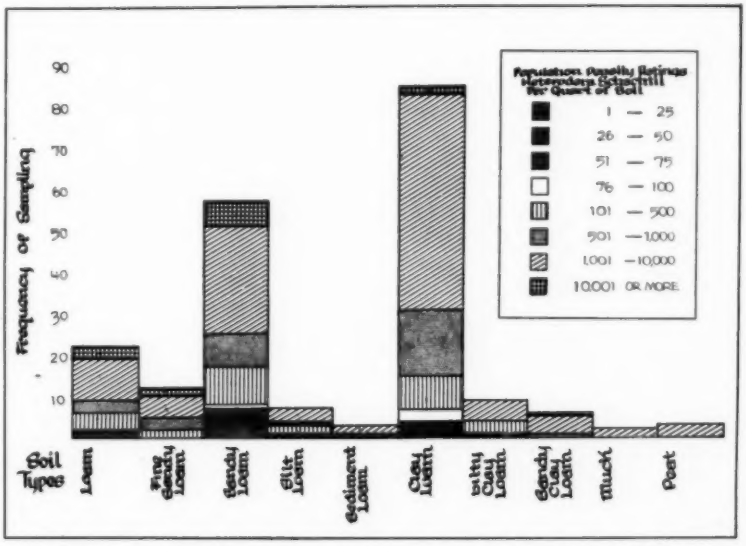

Figure 1.—The frequency of occurrence and densities of *Heterodera schachtii* populations as encountered in various soil types in California, Colorado, and Michigan.

ture can be modified, possibly by soil structure, creating conditions favorable for larval emergence from cysts.

Of the 101 samples collected in the "lighter" soils 90, or 89.10 percent, had dense populations of *H. schachtii*. Out of the 15 samples from silty clay loam and sandy clay loam, one had less than 100 *H. schachtii* larvae per quart of soil. Muck with two samples and peat with three samples were assigned population density ratings 1,001-10,000 larvae per quart of soil for all five samples.

The frequency of susceptible crops is fundamental in the build-up of plant-parasitic nematode populations. Of the 71 fields with clay loam soil assigned population density ratings 501 to 10,001 or more larvae per quart of soil, just eight fields had received a minimum rest period of three years from susceptible crops. On other soil types, satisfactory rest periods were also lacking.

Summary and Conclusions

Infestations of *H. schachtii* were encountered in ten soil types in California, Colorado, and Michigan. Dense *H. schachtii* populations occurred in all soil types. The appearance of dense *H. schachtii* populations in a great number of the clay soil samples suggests the modifying agency of some biotic and/or abiotic factors.

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Gibberellic Acid as a Growth Accelerator on Sugar Beets

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Gibberellic acid (GA) has been shown, by Marth and Mitchell (1, 2)[2] and Wittwer and Bukovac (3, 4) to promote seed germination and accelerate the subsequent growth and development of seedling plants. Since early emergence and rapid initial growth of sugar beets are frequently important in reducing the latter losses due to damping-off organisms and nematodes, it appeared desirable to evaluate the effectiveness of GA on sugar beets in the seedling stage. It also appeared possible that GA would have some effect on sugar production due to probable changes in leaf size or shape. The experiment reported here was designed to provide information on these questions.

Materials and Methods

US 56/2 was the seed variety used for this experiment. The seed had been decorticated and treated with Phygon and Lindane. The plants were grown in used shortening cans, 10 inches in diameter by 12 inches deep, filled with No. 2 grade vermiculite.

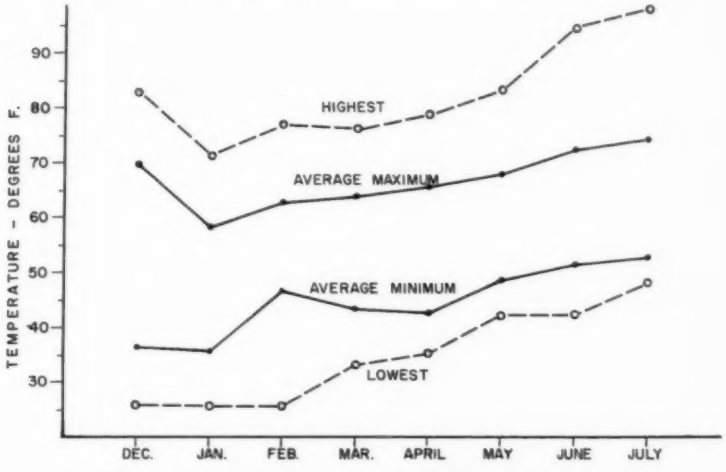

Figure 1.—Temperatures for the growing period of 1957.

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[2] Numbers in parentheses refer to literature cited.

On December 11, 1956, 20 seeds were planted per pot, evenly spaced in a circle, midway between the center and edge, ¾ inch deep. After emergence, the plants were thinned periodically until only 2 plants remained in each pot. Forty such pots were set out in a 10 by 4 randomized pattern 20 to 24 inches apart under natural environmental conditions.

The graph in Figure 1, constructed from data obtained from the U. S. Weather Bureau at Santa Maria, California, shows no radical departure between highest or lowest, or between average maximum and average minimum temperature for the growing period. Pots were turned and re-randomized every 30 days. Hoagland's No. 1 solution (5) was applied daily in sufficient quantities so that solution dripped from holes punched in bottom of cans for 10 to 15 minutes after applying.

After the first root and foliar GA applications were made in January, 1957, the nitrogen level of the solution was doubled to avoid any possibility of spindly growth due to nitrogen deficiency which might have resulted from growth promotive effects of the GA. NO_3-N content of the beet petioles was determined from samples collected periodically. Six weeks prior to harvest, on July 12-15, 1957, the nitrogen level of the solution was reduced and the NO_3-N content of the petioles dropped slightly below the critical level of 1000 p.p.m. This procedure, as outlined by Ulrich (6), was used to obtain as high a sucrose content as possible.

The GA used in this experiment was obtained from two sources. The potassium salt of gibberellic acid called "Gibrel" by Merck & Company and gibberellic acid, as such, from Eli Lilly & Company.[3] The 40 pots had previously been randomly divided into four groups of 10 each. Three different GA treatments were applied to three of the groups while the fourth was left as the untreated control. Treatments were as follows:

A. **Seed treatment:** Prior to planting, the seed was soaked for 48 hours in an aqueous solution of 10 p.p.m. of GA. No further applications of GA were made to this group.

B. **Root treatment.** When the plants had reached the four-leaf stage, GA was injected into the vermiculite as a root application. Five ml. of a 100 p.p.m. solution was injected one inch away from the plant and one and three-quarter inches deep in the vermiculite. Two injections per plant (on opposite sides) equivalent to 1000 micrograms per plant were used per application. Four such

[3] The donation of sufficient quantities of Gibberellic acid for this experiment by Eli Lilly & Company, and Merck & Company, is hereby gratefully acknowledged.

Figure 2.—February 21, 1957, 70 days after planting date.

applications, approximately 30 days apart, were made during the early part of the growing season, from January 16, 1957, to April 25, 1957.

C. **Foliar treatment.** Foliar applications were made at the rate of 0.3 ml. of a 100 p.p.m. GA solution (30 micrograms per plant per application) in the center of the leaf rossette. Four such applications were made on the same time schedule as the root treatment.

D. **Untreated control group.**

Due to the relatively small population involved, root weight, sucrose, top weight, height of tops, and leaf count were all determined on individual-plant basis.

Experimental Results

Emergence of the seedlings was about the same for all of the plants. No significant difference could be detected between the seed treated group and the others. By January 10, 1957, 30 days after planting, all of the plants in the seed treated group were in the four-leaf stage. Six days later the remainder of the plants, none of which had been treated with GA, began to show four-leaf development. All pots had been periodically thinned, until at this stage, only two plants per pot remained. On January 16, 1957, the first root and foliar applications were made.

As shown in Figure 2, the seed treated plants (No. 30) were maintaining their lead 70 days after planting and 30 days after first application of GA to other plants.

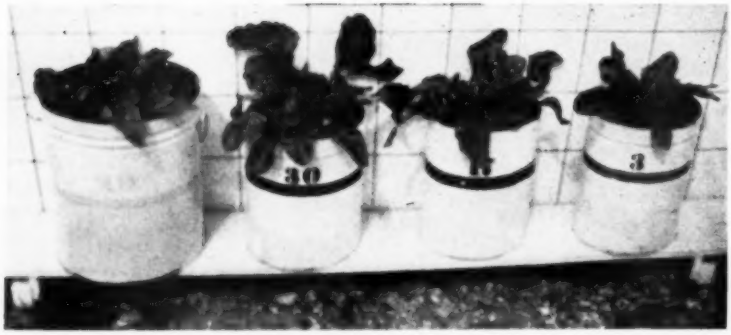

Figure 3.—March 18, 1957, 95 days after planting date.

Figure 4.—April 24, 1957, 135 days after planting date.

On March 18, 1957, Figure 3, 95 days after planting, the seed treated plants still showed a significant difference in top growth. By April 24, 1957, 135 days after planting, Figure 4, this initial growth advantage had leveled out and the root treated plants (No. 39) showed a marked growth acceleration. The foliar treated plants (No. 17) showed very little, if any, response. In all probability the amounts of GA applied to this group were too small. As more than one-half of the growing season had elapsed, no change was made in the amount of GA applied to the leaves.

During the earlier part of this experiment there was some doubt as to whether translocation of the GA through the root system would take place. By May 25, 1957, Figure 5, it was quite obvious that this had occurred. All of the plants receiving the root treatment showed elongation of petioles and much larger

leaves, lighter green in color than the control plants. This unusual top growth is characteristic of a plants response to GA.

Table 1 shows there is no significant difference in sucrose content or root weight between any of the treated groups and the control. The significant difference is in the top weight and top height.

Figure 5.—May 25, 1957, 162 days after planting date and 30 days after fourth application of gibberellic acid.

Table 1.—Yield Data for the Three Methods of Gibberellic Acid Application.

Treatment	Sugar Percent	Root Weight Pounds	Top Weight Pounds	Top Height Inches	Leaves Number
Soil injection	15.89	3.54	3.40	24.7	157
Seed	16.17	3.20	2.00	16.7	139
Leaf	16.80	3.02	1.84	18.9	95
Control	16.01	3.35	2.02	18.3	114
F-Value	1.54	1.31	9.46	18.70	2.11
L.S.D. 5%	N.S.	N.S.	0.69	2.3	N.S.

Required F-value at the 5% level, 2.92; 1% level, 4.68

Summary

1. Three concentrations and three methods of applying GA were used. Seeds were treated only once in a 10 p.p.m. solution. Roots had 1000 micrograms per plant applied, and foliar

treatment was at the rate of 30 micrograms per plant. Both root and foliar applications were made four times during the growing season.

2. Seed treated plants showed accelerated early growth.

3. Root treated plants showed translocation of GA from root to tops resulting in a green top weight nearly equal to the root weight.

4. No response was noted in the foliar treated group.

Literature Cited

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Notes Section

Grading Decorticated Seed for Shape—Decorticated beet seed is normally graded to size by using 7/64 and 10/64 flat screens on a standard seed cleaning machine. It is possible for seed that passes through a 10/64 screen to be much larger than 10/64 in one dimension. This irregularly shaped seed has been found to cause difficulty in most seed drills by gradually accumulating in the bottom of the seed cans and thereby progressively reducing the seeding rate by preventing a complete cell fill. This situation resulted in the initiation of tests on grading for a round shape.

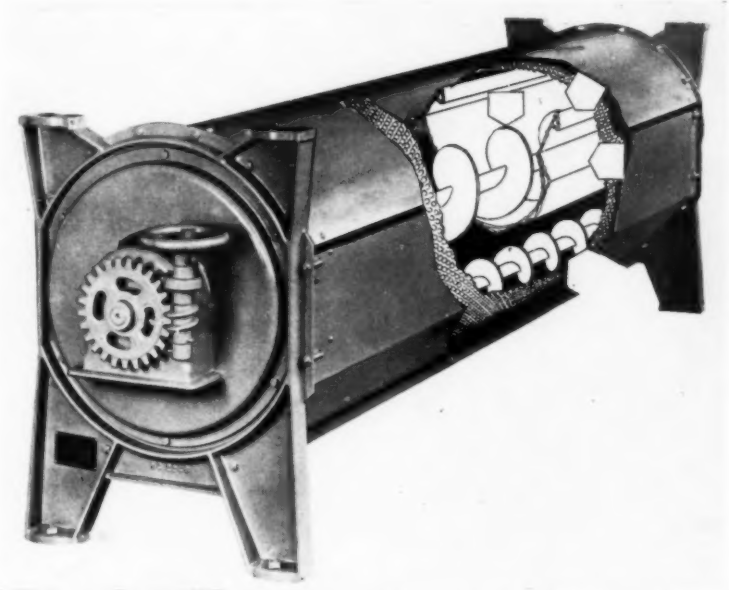

Figure 1.—The No. 11 Uni-Flow unit equipped with a No. 13 indent in service at the Ladner Beet Seed Plant.

The Hart Emerson Company, at Winnipeg, Manitoba, tested recleaning decorticated seed using various sizes of Hart Emerson Indents as well as different shaped Carter discs. The No. 13 indent was finally selected as being capable of removing practically all off-shaped seeds from the decorticated seed. A No. 11 Uni-Flow unit equipped with a No. 13 indent was purchased for the Ladner Beet Seed Plant and all of the decorticated seed

is now graded by this machine. It removes about eight percent of the decorticated seed which is recycled for further polishing. The unit in use is illustrated in the accompanying Figure 1. In addition to selecting for beet seed shape, this machine is useful in removing seeds such as oats and wild radish from decorticated beet seed.

Grading decorticated seed with flat screens with round holes is normally a very slow operation because the seed tends to stick tightly in the screen, particularly as it approaches the diameter of the screen hole. It has been found that such seed flows much more actively over buckwheat screens with triangular holes of equivalent size.

Grading at the Ladner Beet Seed Plant is now accomplished with double the original capacity by using 10/64 buckwheat screens in place of 7/64 round and 15/64 buckwheat in place of 10/64 round. The seed is then regraded over the No. 13 indent to remove off-shaped seed.

Initial tests indicate that the resultant seed should give more uniform cell fill in the seed drill.

F. H. PETO, Director of Agriculture Research.
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